# MONTANA AIR POLLUTION STUDY

## Air Quality Data Summaries for Anaconda-Butte, Billings, Missoula, and Columbia Falls/Hardin/East Helena/Colstrip February, 1981



AIR QUALITY BUREAU
Environmental Sciences Division
Department of Health & Environmental Sciences
Helena, Montana 59620

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## AIR QUALITY DATA SUMMARIES
## FOR
## ANACONDA-BUTTE, BILLINGS, MISSOULA, AND COLUMBIA FALLS/HARDIN/EAST HELENA/COLSTRIP

PREPARED FOR

AIR QUALITY BUREAU

MONTANA DEPARTMENT OF HEALTH
AND ENVIRONMENTAL SCIENCES
HELENA, MONTANA 59620

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February, 1981

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# PREFACE

This document is one of a series of technical reports presenting results from the Montana Air Pollution Study (MAPS), a special air monitoring and health effects project of the Air Quality Bureau, Montana Department of Health and Environmental Sciences. The 1977 Montana Legislature funded MAPS with $1.07 million for the 1977-79 biennium in order to develop an improved understanding of how air pollution affects health in Montana. The 1979 Legislature continued MAPS with a funding of $350,000 to complete the monitoring through June 1980 and provide for data analysis.

The various activities undertaken as part of the MAPS effort have been grouped into five major categories for purposes of project management: Health Effects, Air Quality, Meteorology/Modeling, Emission Inventory, and Statistics and Data Systems. From each of these technical areas one or more technical reports prepared by the personnel directly involved in the study efforts will be presented. In addition, an overall summary report for the public will be prepared.

This specific report presents the final results of the MAPS air quality monitoring study from 1 January 1978 through 30 June 1980 in Anaconda-Butte, Billings, Missoula, and Columbia Falls/Hardin/East Helena/Colstrip. The study was designed and coordinated by Hal Robbins and Dave Maughan. Mr. Robbins is presently Chief of the Bureau and Project Manager of MAPS, while Mr. Maughan is responsible for special projects in the Bureau. James Gelhaus, Partner and Senior Meteorologist, Bison Engineering/Research, prepared this report under contract.

The reader must be cautious in the use and analysis of any of the presented data. The following comments must be noted.

1. The chemical analysis of the trace element data was performed using a partial digestion procedure with concentrated nitric acid. In some cases the presented data may be lower (5-30%) than those using a total digestion process, depending on the element in question.
2. The siting of various instruments for the MAPS project was conducted prior to an established criteria for ambient air pollution monitoring siting. This means that the use of terms such as "violations" in this report may be misleading. Violations do not exist unless the sampling site and methodologies conform to the established criteria. The Lions' Park site in Missoula, for example, does not meet the proper siting criteria for total suspended particulates. Throughout this report comparisons are made to the appropriate State and Federal standards. The use of the term "violation," therefore, does not in any way confirm that a violation truly exists, since no comparisons are made to the siting and methodology requirements.
3. Despite the MAPS staff's best efforts to generate high-quality data, a problem with the dichotomous sampler calibration was discovered after the end of the project. The staff has discovered that the fine fraction may be overestimated by between 10 to 25 percent. Initial estimates suggest that the error is probably a relatively constant bias for each site. The bias, however, probably is not consistent among the sites. The Bureau is continuing to study this problem. <u>No</u> attempt was made to correct any of the data presented for this bias.

# EXECUTIVE SUMMARY

The Montana Air Pollution Study (MAPS), in addition to the Air Quality Bureau's normal monitoring activities, has provided valuable data on the air pollution levels in the Anaconda-Butte, Billings, Missoula, and Columbia Falls/Hardin/East Helena/Colstrip areas. The data will and already have provided insight into a clearer understanding of air pollution health effects; established trends as to pollution levels; and described relationships among meteorology, air pollution emissions, and air quality. In the combined effort of MAPS and the normal monitoring network, data have been collected on all criteria pollutants (total suspended particulates (TSP), sulfur dioxide, nitrogen dioxide, photochemical oxidants, hydrocarbons, and carbon monxide), fine particulates and trace elements.

In the Anaconda-Butte area, monitoring data revealed concentrations of total suspended particulates in excess of the federal and Montana standards. Although no standard has been adopted, fine particulate data provided information on the concentrations and trends among the different sizes of particles in the air. Trace element data showed higher levels of aluminum, iron, manganese, and nitrate in Butte, with higher levels of asenic, cadmium, copper, nickel, zinc, and sulfates in Anaconda. Gaseous pollutant data showed ozone, nitrogen dioxide, and carbon monoxide to be below all standards. Only sulfur dioxide exceeded the standards.

In Billings MAPS data showed total suspended particulates in excess of the federal primary standard at one location and in excess of the federal secondary and Montana standards at several locations. Gaseous pollutant data revealed ozone levels near the federal standard but in slight excess of the Montana standard. Carbon monoxide and nitrogen dioxide levels were below all federal and Montana standards at the MAPS sites. Sulfur dioxide concentrations were below the federal and Montana standards at all locations except for the Laurel site. At Laurel concentrations of sulfur dioxide in excess of the Montana and federal one-, three-, and twenty-four-hour standards were recorded.

In Missoula total suspended particulate levels exceeded federal and Montana standards at most stations. Among the gaseous pollutants, carbon monoxide exceeded both the federal and Montana standards.

In the Columbia Falls, Kalispell, Ronan, and East Helena areas, particulate concentrations exceeded federal and state standards. Concentrations of particulates were below the standards in the Hardin and Colstrip areas. Sulfur dioxide data in East Helena also were at or below the federal and state standards.

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# I. INTRODUCTION

The concept of developing a major study of air pollution health effects originally arose from a discussion concerning unusually high death rates from chronic pulmonary disease and lung cancer in several Montana counties, which were identified in a review of death certificates by the Montana Department of Health and Environmental Sciences' Bureau of Records and Statistics. Since many researchers feel these categories of lung diseases are caused or worsened by high air pollution levels, a more extensive study of the subject seemed warranted. Prior to this study, only major medical research universities and the federal government conducted air pollution and health research, and the results generally were seen as not applicable to Montana's unusual terrain and meteorology. Consequently, the Air Quality Bureau recommended to the Montana Legislature that a study be undertaken, and the 1977 Legislature enacted House Bill (HB) 250 to mandate and fund such a project.

In response to the passage of HB 250, the Air Quality Bureau developed a proposed project plan for the Montana Air Pollution Study (MAPS), to be conducted during the 1977-79 biennium. (Additional funding by the Legislature continued the MAPS effort through the 1979-81 biennium.) Drafts of the proposed plan were made available in May 1977 and public hearings were held. The approved plan offered three major goals of the effort:

Develop a comprehensive body of information on air pollution levels, meteorology, pollutant emissions, and topography, and determine how these factors relate to the effects or impacts on the public;

Determine where possible the health impacts of selected air pollutants on the populace of specific areas of the state (areas designated in the plan were Anaconda-Butte, Billings, Missoula, Columbia Falls, East Helena, and the Colstrip-Hardin southeast coal development region);

Develop an early warning system to prevent the occurrence of episodes of high air pollutant levels that could cause possible health damage.

The plan further defined nine specific objectives designated to implement these goals:

1. Comprehensive information system;
2. Air resources modeling system;
3. Air resources data bank;
4. Ambient air monitoring;
5. Meteorological studies;
6. Emission inventory;
7. Health monitoring;
8. Health impact correlation; and
9. Early warning system.

Figure A is a flow chart illustrating how the various specific objectives of MAPS were inter-related. Under MAPS, four areas served as basic data-gathering activities - air quality, meteorology, and emission inventory, all of which amplified existing Air Quality Bureau functions, plus health effects monitoring,

which was an unprecedented activity in the Pureau.

A comprehensive information system tied all the above activities together and facilitated access to the data generated by MAPS and the Bureau. The air quality and meteorology data were used for analysis with the health data to develop the modeling and early warning systems. Through regular analysis, the data also assisted in the identification of sources and causes of air pollution. The meteorological data served as the major resource to develop the modeling system, along with the air quality and emissions data. The modeling system not only contributed to the early warning system, but also facilitated the making of development and planning decisions. The air quality and health effects data were the primary components required to develop health effets relationships, although the meteorological and emission data assisted in the interpretation of those relationships in unusual cases.

The May 1977 project plan also defined an organizational structure for coordinating the MAPS project within the staff of the Department, mainly in the Air Quality Bureau, and established five advisory committees to assist the Bureau in tapping all the relevant expertise available in the state.

During the development of the project plan, the Bureau staff sought expertise and guidance not only from within the state, but also from representatives of the federal Environmental Protection Agency and various individuals and firms involved in environmental consulting and contracting. The concern for developing an adequate and readily accessible data base, as expressed in the first project goal, was given additional emphasis in response to the general opinion of outside experts. This report summarizes the MAPS effort to establish an air quality data base for the study areas outlined in HB 250.

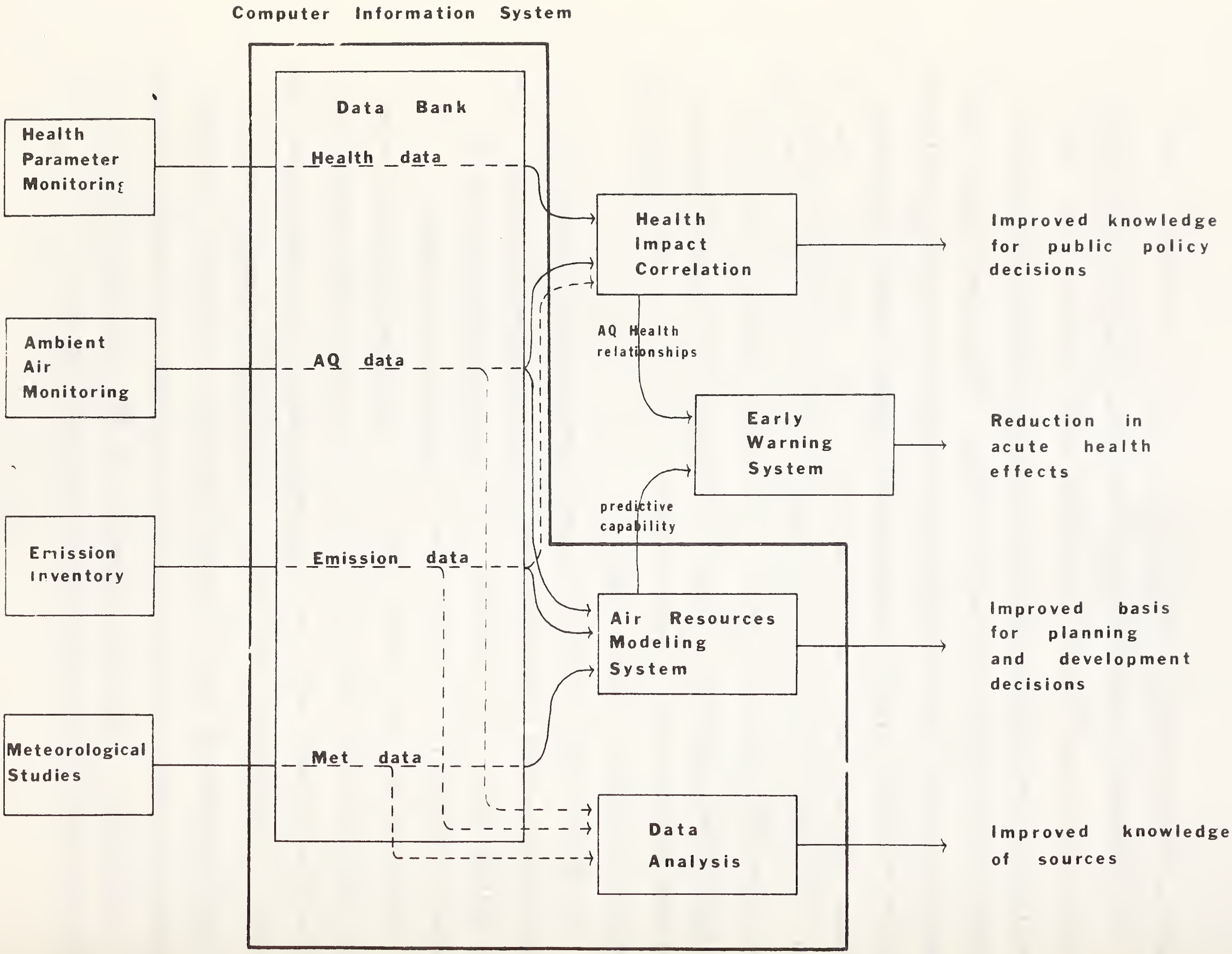



Figure A. Inter-relationship Among MAPS' Nine Operating Objectives

# II. ANACONDA-BUTTE

This chapter summarizes the ambient air quality data collected in the cities of Anaconda and Butte, as well as portions of the surrounding areas. Data on total suspended particulate (for a description of the technical terms used, see the Glossary at the end of this report), sulfur dioxide, total hydrocarbons, carbon monoxide, ozone, and inhalable particulates are discussed.

The populated areas of Butte and vicinity range in elevation from approximately 5200 feet above sea level near the Stauffer Chemical Plant (about six miles west of Butte) to approximately 6000 feet above sea level at Walkerville (about one mile north of Butte). The city of Butte is located about four miles west of the Continental Divide. The area experiences a climate characteristic of its high elevation, i.e., extreme cold spells, long snow cover, and a short growing season are normal for the area. Frequent temperature inversions, especially in the winter months, tend to trap and hold pollutants. Major potential sources of air pollution in the area include a large open pit copper mine, an ore concentrator, an elemental phosphorous plant, a tepee burner, and several hot mix plants. Automobiles, home heating devices, and windblown or fugitive dust also contribute to the air pollution levels.

The Anaconda area's elevation varies from about 5200 feet above sea level in the town to 10,600 feet in the mountains to the south. Anaconda is located at the south end of the Deer Lodge Valley and northeast of the Anaconda-Pintlar

Wilderness area. The valley experiences temperature inversions, which tend to trap and hold pollutants, approximately 40 percent of the time on an annual average. The Anaconda Company copper smelter, on the east edge of town, is the major industrial complex in the area and the source of approximately 80 percent of the sulfur dioxide emissions in the state. The smelter also is a source of particulates. (The smelter was closed in the autumn of 1980, and reopening is not anticipated at this writing.)

A. Methodology

Prior to MAPS, the Air Quality Bureau operated several air quality sampling stations in the Anaconda-Butte area. With the MAPS effort, the number of monitoring stations and the air pollutants monitored were increased. Primary emphasis of the additional samplers was to monitor the areas of greatest population exposure, i.e., central Anaconda and Butte. Table 1 lists the various sampling sites operated during MAPS in the Anaconda-Butte area. These sites also are shown in Figures 1 and 2. Table 1 also lists the parameters sampled, the analysis method used in obtaining the data, and the area type.

The Lincoln School sampling site is located in central Anaconda in a residential area. The C-Hill site is south of Anaconda 1.5 miles in a rural location on top of a bare hill. The Post Office sampling site is located in central Anaconda in a commercial setting. The Mill Creek site is three miles southeast of Anaconda in a rural setting. At the junction of Highway 48 and the county highway to Galen three miles east-northeast of Anaconda, the Highway Junction sampling site was operated. (The setting is rural agricultural.) All of the Anaconda area sampling sites were located within two miles of Anaconda.

At the Tierney residence in south Ramsay, one sampler was operated for total suspended particulates. In the Butte area, eight stations were operated at one

TABLE 1

BUTTE/ANACONDA SAMPLING SITES AND PARAMETERS

| Site | Location (Area Type) | Parameters Sampled | Analysis Method |
|---|---|---|---|
| Lincoln School | Central Anaconda (Residential) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Fine Particulates | Gravimetric-Dichotomous Air Sampler |
| | | Sulfur Dioxide | Flame Photometric |
| | | Nitrogen Dioxide | Chemiluminescence |
| | | Ozone | Chemiluminescence |
| | | Total Hydrocarbons | Flame Ionization |
| | | Trace Elements | Atomic Absorption-High Volume Air Samples |
| | | Trace Elements | Atomic Absorption-Membrance Sampler |
| C-Hill | S. of Anaconda 1.5 mi (Rural) | Sulfur Dioxide | Coulometric |
| Post Office | Central Anaconda (Commercial) | Sulfur Dioxide | Coulometric |
| Mill Creek | SE of Anaconda 3mi. (Rural) | Sulfur Dioxide | Coulometric |
| | | | Pulsed Fluorescent (June 80) |
| Hiway 48 Jct. | ENE of Anaconda 3 mi. (rural) | Sulfur Dioxide | Coulometric |
| | | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements | Atomic Absorption-High Volume Air Samples |
| Tierney Res. | S. Ramsay (Residential) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| Floral Park Fire Station | SE Butte (residential) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Fine Particulates | Gravimetric-Dichotomous Air Sampler |
| | | Trace Elements | Atomic Absorption-High Volume Air Samples |
| Dr. Canty Residence | NW Butte (Residential) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements | Atomic Absorption-High Volume Air Samples |
| Gilman Construction | S. Butte (Industrial) | Total Suspended Particulates | |
| | | Trace Elements | |
| Alpine West | NE Butte | Carbon Monoxide | Nondispersive-Infra-red |

| Site | Location | Parameters Sampled | Analysis Method |
|---|---|---|---|
| Richer Residence | S. of Butte 3 mi. (Rural) | Total Suspended Particulates | |
| | | Trace Elements | |
| Atkins Residence | NW Butte (Residential) | Total Suspended Particulates | |
| | | Trace Elements | |
| Greeley School | NE Butte (Residential-Commerical) | Total Suspended Particulates | |
| | | Trace Elements | |
| Hebgen Park | Northcentral Butte (Residential) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Fine Particulates | Gravimetric-Dichotomous Air Sampler |
| | | Trace Elements | Atomic Absorption-High Volume Air Samples |
| | | Trace Elements | Atomic Absorption - Membrane Sampler |
| | | Carbon Monoxide | Gas Chromatograph |
| | | Carbon Monoxide | Nondispersive Infra-red |
| | | Sulfur Dioxide | Coulometric |
| | | Nitrogen Dioxide | Chemiluminescence |
| | | Total Hydrocarbons | Flame Ionization |
| | | Methane Hydrocarbons | Flame Ionization |
| | | Ozone | Chemiluminescence |
| | | Beta Scatter | Nephelometer |

Figure 1

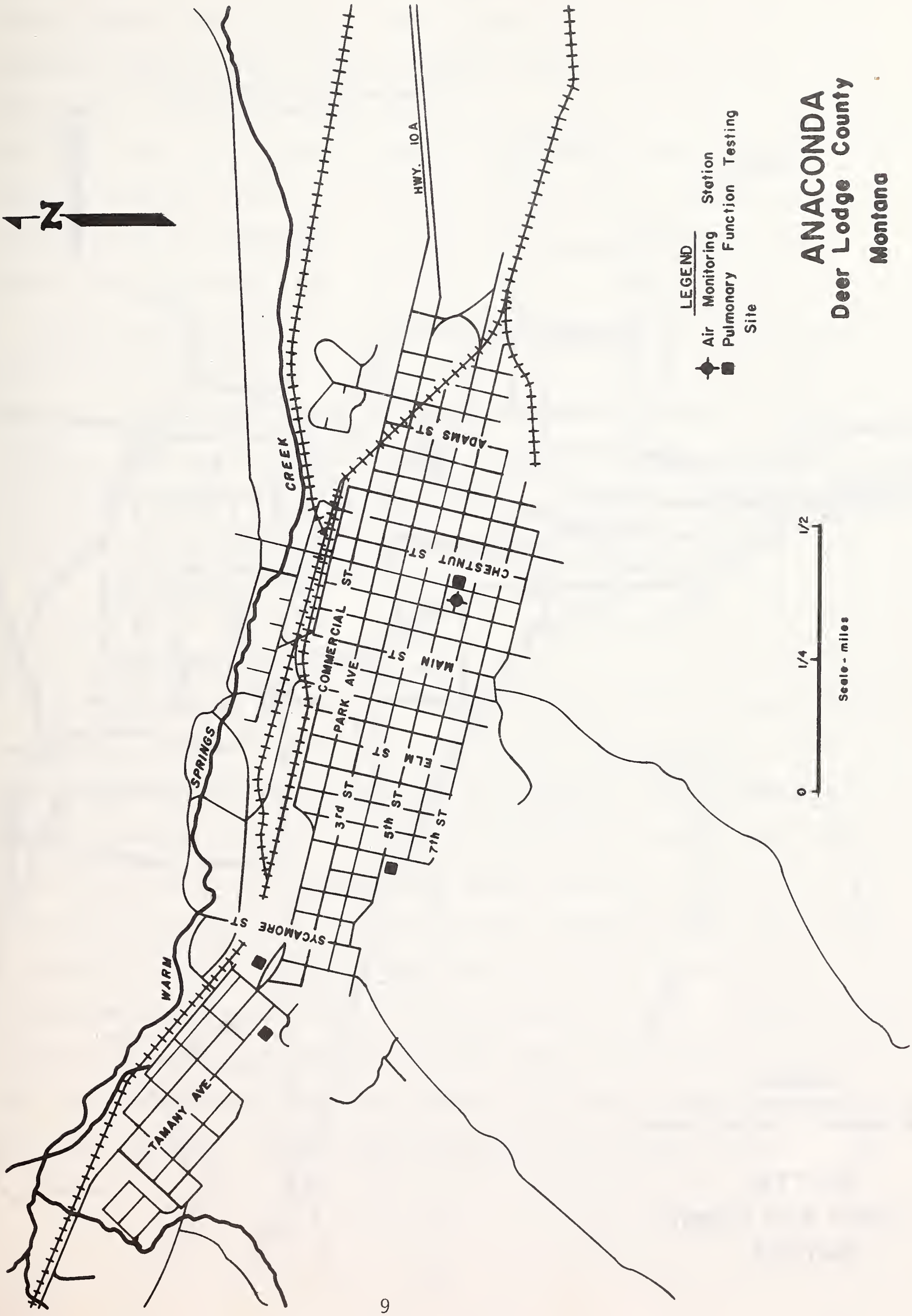
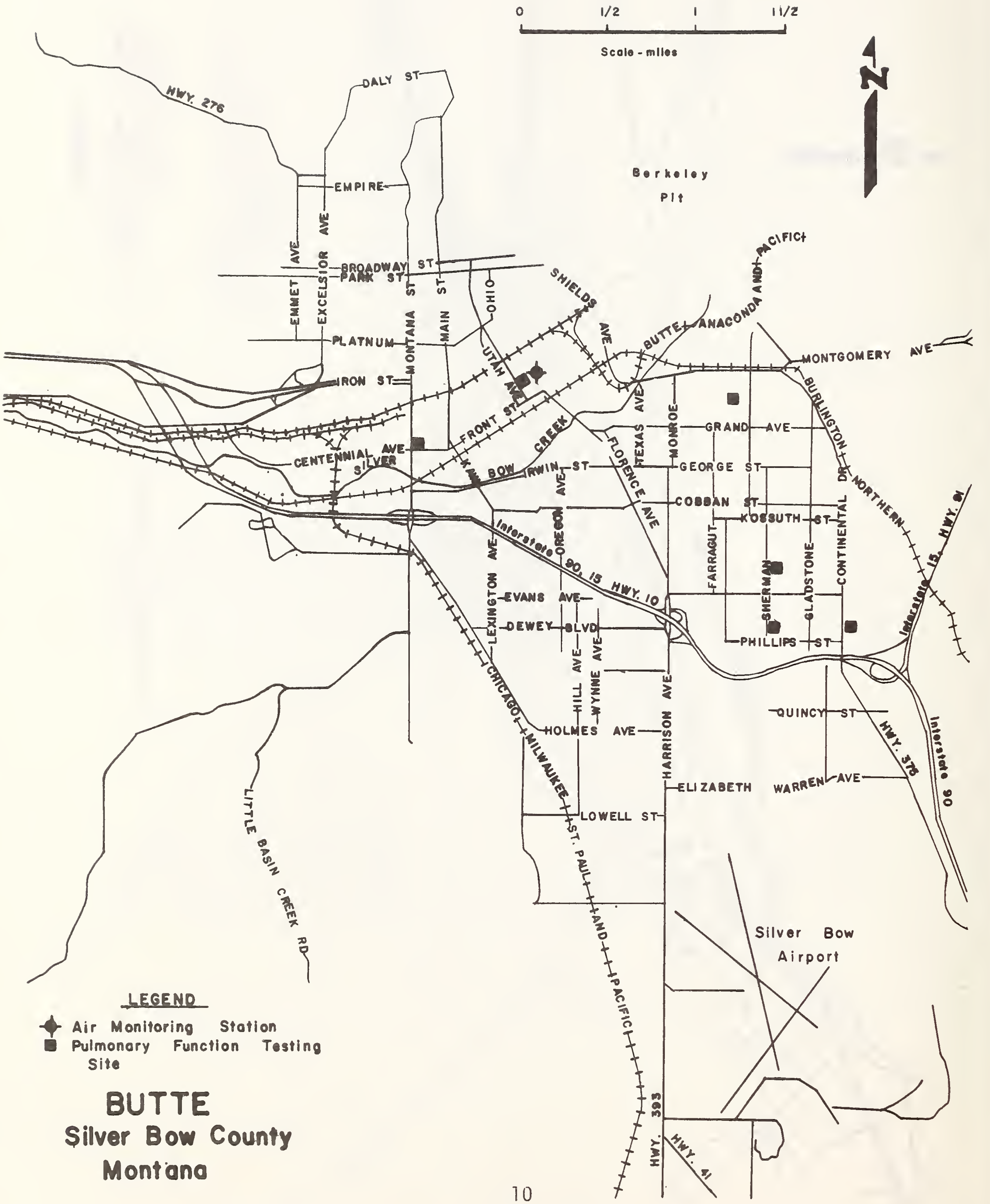

ANACONDA
Deer Lodge County
Montana
LEGEND
Air Monitoring Station
Pulmonary Function Testing Site
0
1/4
1/2
Scale - miles
N
HWY. 10A
ADAMS ST
CHESTNUT ST
MAIN ST
ELM ST
COMMERCIAL ST
PARK AVE
3rd ST
5th ST
7th ST
SYCAMORE ST
TAMANY AVE
WARM
SPRINGS
CREEK

Figure 2


0 1/2 1 11/2
Scale - miles
N
Berkeley Pit
HWY. 276
DALY ST
EMPIRE
EMMET AVE
EXCELSIOR AVE
BROADWAY ST
PARK ST
MONTANA ST
MAIN ST
OHIO
SHIELDS
PLATNUM
IRON ST
UTAH AVE
FRONT ST
CENTENNIAL AVE
SILVER BOW CREEK
BUTTE ANACONDA AND PACIFIC
MONTGOMERY AVE
BURLINGTON NORTHERN
GRAND AVE
GEORGE ST
TEXAS AVE
MONROE
FLORENCE AVE
COBBAN ST
KOSSUTH ST
FARRAGUT
SHERMAN
GLADSTONE
CONTINENTAL DR
Interstate 15 HWY. 91
Interstate 90, 15 HWY. 10
LEXINGTON AVE
OREGON AVE
EVANS AVE
DEWEY BLVD
HILL AVE
WYNNE AVE
PHILLIPS ST
HARRISON AVE
QUINCY ST
HOLMES AVE
CHICAGO MILWAUKEE ST. PAUL AND PACIFIC
HWY. 375
Interstate 90
ELIZABETH WARREN AVE
LOWELL ST
LITTLE BASIN CREEK RD
Silver Bow Airport
HWY. 393
HWY. 41
LEGEND
Air Monitoring Station
Pulmonary Function Testing Site
BUTTE
Silver Bow County
Montana

time or another during the study. These included the Floral Park Fire Station (southeast Butte-residential area), Dr. Canty residence (northwest Butte - residential area), Gilman Construction (south Butte - industrial area), Alpine West (northeast Butte - mixed commercial and industrial area), Richer residence (three miles south of Butte - rural area), Atkins residence (northwest Butte - residential area), Greeley School (northeast Butte - mixed residential and commercial area), and Hebgen Park (northcentral Butte - residential area).

The data are presented as follows by air pollutant, starting with the most common (total suspended particulates), through the related parameters, and gaseous pollutants. Comparisons are made with the Montana Ambient Air Quality Standards (MAAQS) and the National Ambient Air Quality Standards (NAAQS), which are listed in Tables 2 and 3, respectively. The national or federal standards include both the primary and secondary standards.

B. Presentation of Results

1. Total Suspended Particulates

Total suspended particulate concentrations as measured by high-volume air samples are summarized in Tables 4 and 5. Table 4 lists the highest, second-highest, and third-highest concentrations of particulates measured during the time periods shown. The second-highest and third-highest concentrations are shown, in addition to the highest, as the Montana and federal ambient air standards allow one excursion of the twenty-four hour standard during a year without a violation occurring. The second excursion at the same site constitutes a violation of the standard. Among the ten sites shown in Table 4, concentrations exceeding the twenty-four hour federal primary value of 260 micrograms per cubic meter (ug/$m^3$) occurred at the Lincoln School, Floral Park, Dr. Canty residence, and Hebgen Park sites. However, only the Hebgen Park site had a second

TABLE 2

MONTANA AMBIENT AIR QUALITY STANDARDS

| Pollutant | Standard ($ug/m^3$) | (ppm) | Averaging Time |
|---|---|---|---|
| Carbon Monoxide | --- | 23 | 1-hour* |
| | --- | 9 | 8-hour* |
| Fluoride(forage) | --- | 20 ug/g -- | Month+ |
| Hydrogen Sulfide | --- | 0.05 | 1-hour* |
| Lead | 1.5 | --- | 90-day+ |
| Nitrogen Dioxide | --- | 0.30 | 1-hour* |
| | --- | 0.05 | Annual |
| Ozone | --- | 0.10 | 1-hour* |
| Settled Particulate | --- | $10 g/m^2$ --- | 30-day+ |
| Sulfur Dioxide | --- | 0.50 | 1-hour[a] |
| | --- | 0.10 | 24-hour* |
| | --- | 0.02 | annual |
| Total Suspended Particulates | 200 | --- | 24-hour* |
| | 75 | --- | Annual |
| Visibility | --- | $3x10^{-5}$ per meter | Annual |

*Not to be exceeded more than once per year
+Not to be exceeded
[a]Not to be exceeded more than eighteen times in any twelve consecutive months

TABLE 3

FEDERAL AMBIENT AIR QUALITY STANDARDS

| Pollutant | Primary (ug/m$^3$) | Primary (ppm) | Secondary (ug/m$^3$) | Secondary (ppm) | Averaging Time |
|---|---|---|---|---|---|
| Total Suspended Particulates | 75 | --- | 60 | --- | Annual |
| | 260 | --- | 150 | --- | 24-hour* |
| Sulfur Dioxide | 80 | 0.03 | --- | --- | Annual |
| | 365 | 0.14 | --- | --- | 24-hour* |
| | --- | --- | 1,300 | 0.5 | 3-hour* |
| Carbon monoxide | 10,000 | 9.0 | --- | --- | 8-hour* |
| | 40,000 | 35.0 | --- | --- | 1-hour* |
| Photochemical Oxidants | 240 | 0.12 | --- | --- | 1-hour+ |
| Hydrocarbons | 160 | 0.24 | --- | --- | 3-hour (6-9 a.m.)* |
| Nitrogen Oxides | 100 | 0.05 | --- | --- | Annual |
| Lead | 1.50 | --- | --- | --- | Quarter |

*Not to be exceeded more than once/year.
+Not to be exceeded more than one day a year.

TABLE 4

BUTTE/ANACONDA AREA TOTAL SUSPENDED PARTICULATE SUMMARY
(Values in micrograms per cubic meter)

| Site | Maximum Readings High | Maximum Readings 2nd High | Maximum Readings 3rd High | Arithmetic Mean | Arithmetic Std. Dev. | Geometric Mean | Geometric Std. Dev. | No. of Observ. | Time Period |
|---|---|---|---|---|---|---|---|---|---|
| Lincoln School | 303 | 202 | 200 | 54 | 35 | 42 | 1.8 | 469* | May 78-Jun 80 |
| Hiway 48 Jct. | 155 | 94 | 84 | 36 | 22 | 30 | 1.8 | 111 | Jan 78 - Jun 80 |
| Tierney Res. | 90 | 84 | 83 | 36 | 22 | 30 | 1.8 | 133 | Jan 78 - Jun 80 |
| Floral Park | 314 | 166 | 138 | 63 | 34 | 55 | 1.7 | 139 | Nov 78 - Jun 80 |
| Dr. Canty Res. | 322 | 216 | 197 | 74 | 59 | 58 | 2.0 | 180 | Jun 78 - Jun 80 |
| Gilman | 191 | 139 | 118 | 66 | 43 | 55 | 1.9 | 24 | Jan 78 - May 78 |
| Richer Res. | 53 | 45 | 45 | 22 | 10 | 19 | 1.7 | 49 | Jan 78 - Nov 78 |
| Atkins Res. | 60 | 50 | 47 | 28 | 17 | 23 | 2.0 | 14 | Jan 78 - Apr 78 |
| Greeley School | 242 | 220 | 214 | 84 | 47 | 72 | 1.7 | 131 | Jan 78 - Jun 80 |
| Hebgen Park | 306 | 304 | 270 | 83 | 49 | 67 | 1.8 | 479* | May 78 - Jun 80 |

*Sampling frequency greater than standard every sixth day schedule

TABLE 5

BUTTE/ANACONDA AREA MONTHLY AVERAGE PARTICULATE LEVELS
(Values in micrograms per cubic meter)

| Month | Lincoln School Max | Lincoln School Ave | Hiway Jct. Max | Hiway Jct. Ave | Tierney Res. Max | Tierney Res. Ave | Floral Park Max | Floral Park Ave | Dr. Canty Res. Max | Dr. Canty Res. Ave | Greeley Sch. Max | Greeley Sch. Ave | Hebgen Park Max | Hebgen Park Ave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 78 | --- | --- | 65 | 38 | 68 | 32 | --- | --- | --- | --- | 173 | 81 | --- | --- |
| Feb | --- | --- | 54 | 26 | 52 | 25 | --- | --- | --- | --- | 135 | 74 | --- | --- |
| Mar | --- | --- | 94 | 39 | 43 | 26 | --- | --- | --- | --- | 195 | 135 | --- | --- |
| Apr | --- | --- | 25 | 18 | 29 | 22 | --- | --- | --- | --- | 111 | 69 | --- | --- |
| May | 35 | 24 | 24 | 20 | 23 | 19 | ---- | --- | --- | --- | 86 | 79 | 106 | 40 |
| Jun | 77 | 45 | 36 | 27 | 23 | 19 | --- | --- | 54 | 49 | 94 | 54 | 133 | 56 |
| Jul | 65 | 41 | 42 | 31 | 62 | 38 | --- | --- | 61 | 45 | 81 | 60 | 83 | 53 |
| Aug | 61 | 41 | 43 | 36 | 70 | 46 | --- | --- | 70 | 51 | 82 | 65 | 93 | 58 |
| Sep | 73 | 39 | 38 | 28 | 34 | 26 | --- | --- | 99 | 53 | 113 | 60 | 105 | 59 |
| Oct | 97 | 55 | 73 | 40 | 50 | 39 | --- | -- | 124 | 69 | 142 | 95 | 146 | 92 |
| Nov | 101 | 46 | 155 | 68 | 81 | 47 | 111 | 57 | 149 | 63 | 130 | 94 | 158 | 83 |
| Dec | 59 | 22 | 57 | 28 | 25 | 14 | 97 | 50 | 169 | 63 | 179 | 71 | 155 | 69 |
| Jan 79 | 68 | 39 | 40 | 30 | 73 | 38 | 72 | 60 | 163 | 86 | 196 | 109 | 166 | 92 |
| Feb | 70 | 23 | 59 | 37 | 49 | 36 | 98 | 49 | 113 | 43 | 136 | 84 | 179 | 59 |
| Mar | 303 | 90 | 38 | 26 | 34 | 22 | 112 | 68 | 181 | 76 | 158 | 96 | 225 | 102 |
| Apr | 94 | 40 | --- | --- | 80 | 43 | 109 | 52 | 148 | 54 | 86 | 72 | 98 | 58 |
| May | 95 | 55 | 86 | 72 | 75 | 48 | 80 | 53 | 85 | 54 | 144 | 95 | 155 | 75 |
| Jun | 72 | 47 | 53 | 46 | 62 | 46 | 85 | 57 | 118 | 83 | 121 | 88 | 169 | 84 |
| Jul | 84 | 54 | 67 | 50 | 62 | 49 | 66 | 57 | 124 | 96 | 105 | 82 | 173 | 89 |
| Aug | 100 | 51 | 66 | 50 | 74 | 40 | 75 | 46 | 100 | 53 | 113 | 55 | 124 | 72 |
| Sept | 202 | 90 | 53 | 43 | 83 | 56 | 80 | 52 | 136 | 101 | 122 | 90 | 139 | 101 |
| Oct | 161 | 74 | 63 | 43 | 75 | 48 | 79 | 66 | 133 | 80 | 131 | 96 | 192 | 88 |
| Nov | 168 | 89 | 14 | 14 | 83 | 51 | -- | --- | 197 | 108 | 242 | 197 | 270 | 128 |
| Dec | 146 | 53 | --- | --- | 84 | 37 | 117 | 117 | 216 | 70 | 174 | 95 | 306 | 128 |
| Jan 80 | 108 | 49 | 48 | 34 | 59 | 42 | 138 | 108 | 322 | 131 | 220 | 157 | 252 | 110 |
| Feb | 145 | 76 | 50 | 32 | 67 | 44 | 166 | 81 | 192 | 102 | 49 | 38 | 224 | 101 |
| Mar | 84 | 60 | 20 | 17 | 21 | 17 | 103 | 67 | 111 | 59 | 109 | 77 | 167 | 80 |
| Apr | 165 | 88 | 76 | 48 | 90 | 45 | 131 | 69 | 160 | 94 | 103 | 84 | 198 | 109 |
| May | 67 | 42 | 22 | 22 | 35 | 31 | 314 | 86 | 107 | 52 | 55 | 45 | 113 | 66 |
| Jun | 97 | 53 | 57 | 35 | 36 | 28 | 56 | 50 | 51 | 40 | 64 | 58 | 50 | 46 |

excursion of the federal primary standard. A second excursion does not automatically constitute a violation of the standard as both excursions must occur within the same year. In the case of the Hebgen Park site, both excursions did occur during 1979. The federal secondary twenty-four hour standard was exceeded at seven sites, and second excursions occurred at Lincoln School, Floral Park, Dr. Canty residence, Greeley School, and Hebgen Park. The federal secondary standard for particulates is 150 ug/m$^3$. The highest twenty-four hour particulate concentration measured was 322 ug/m$^3$, which occurred at the Dr. Canty residence. The Montana twenty-four hour particulate value of 200 ug/m$^3$ was exceeded at the Lincoln School, Floral Park, Dr. Canty residence, Greely School, and Hebgen Park sites. Second excursions of the Montana standard occurred at Lincoln School, Dr. Canty residence, Greeley School, and Hebgen Park sites.

Table 4 also lists the arithmetic mean, arithmetic standard deviation, geometric mean, geometric standard deviation, and number of observations taken. Both the arithmetic and geometric means are listed in Table 4, as the Montana annual standard is based on an arithmetic mean of any twelve consecutive months, whereas the federal primary and secondary annual standards are based on a geometric mean of any twelve consecutive months. The federal primary annual standard of 75 ug/m$^3$ was not exceeded at any of the sites. However, the federal secondary standard of 60 ug/m$^3$ was exceeded at the Greeley School and Hebgen Park sites. The Montana annual standard of 75 ug/m$^3$ (arithmetic) also was exceeded at the Greeley School and Hebgen Park sites. The maximum arithmetic mean occurred at the Greeley School site (84 ug/m$^3$). The maximum geometric mean also occurred at the Greeley School site (72 ug/m$^3$). All samplers except the high-volume samplers at the Lincoln School and Hebgen Park sites were run on the standard schedule of one sample every six days. The other two samplers were operated almost every day.

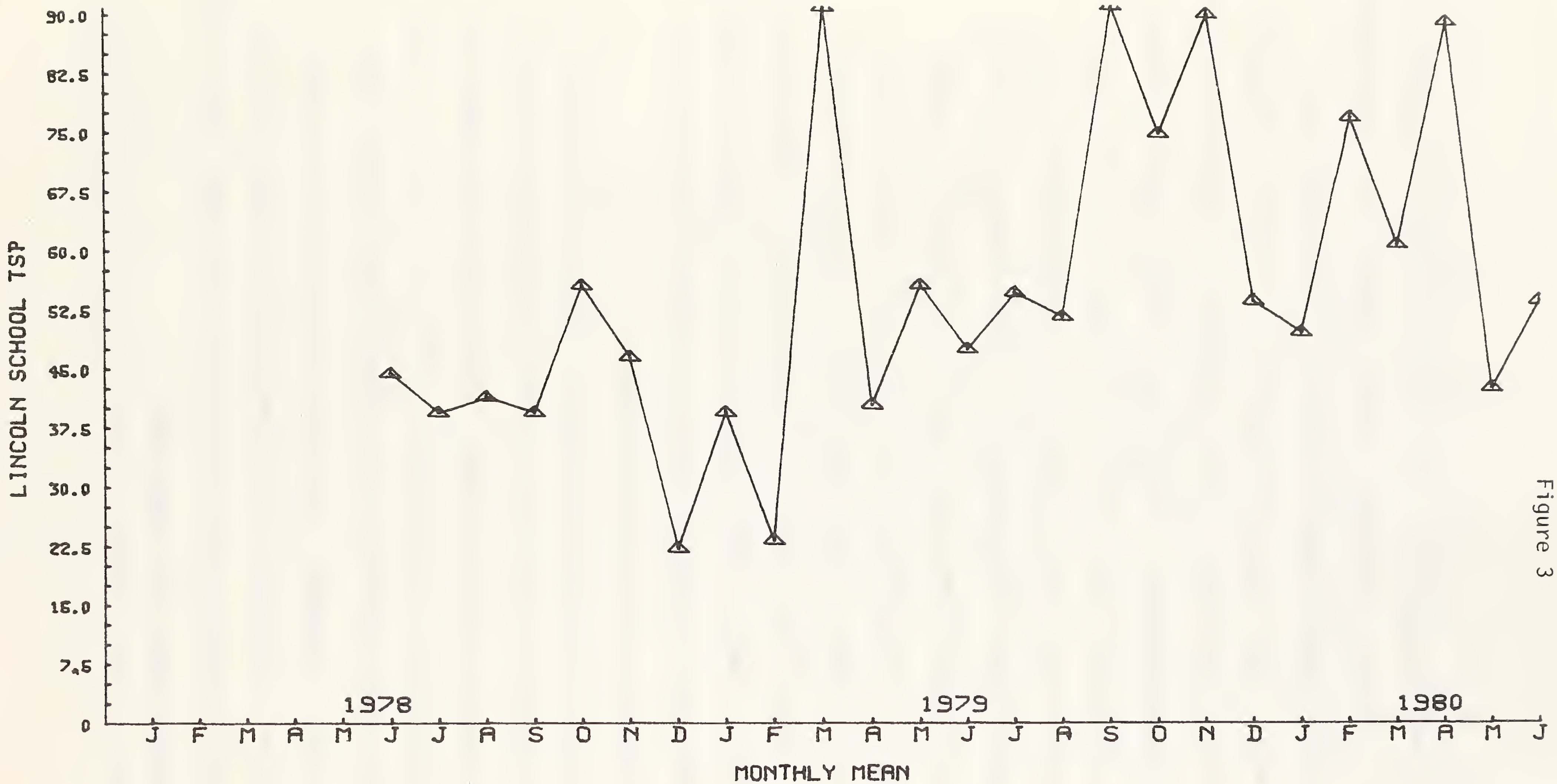
Table 5 lists the monthly arithmetic average total suspended particulate concentrations measured at seven of the longest running samplers in the Anaconda/Butte area. Also listed are the maximum twenty-four hour concentrations of particulates for each month. These same monthly averages are shown for the Lincoln School, Hig way Junction, Floral Park, Dr. Canty residence, and Hebgen Park sites in Figures 3 through 7, respectively. In the figures, monthly averages were not plotted if less than four samples were available for averaging. At the Lincoln School site, the trend in Table 5 shows highest average concentrations in the autumn (September-November) with a few exceptions. A high monthly average was recorded in March 1979 (90 ug/m$^3$) and again in April 1980 (88 ug/m$^3$). Lowest average concentrations occurred during winter (December-February). At the Highway Junction site, the trend is not as well defined. Highest average concentration occurred in May 1979 (72 ug/m$^3$), while lowest concentrations occurred mainly during the summer. Figures 3 and 4 do not describe any apparent seasonal trend. However, Figure 3 does indicate an increasing average particulate concentration at Lincoln School as the study progressed.

Data collected at the Tierney residence in Ramsay shows a trend toward higher average concentrations in autumn versus lower average concentrations in late spring and early summer. Monthly averages at the Tierney site appear to be higher most months during 1979 than either 1978 or 1980.

The Floral Park site data collected in Butte show a very different trend than that at previous sites discussed. Little variation from month to month occurs with the exception of December 1979 and January 1980. Highest average concentrations occurred in December 1979 (117 ug/m$^3$-one sample only), whereas the lowest average occurred in August 1979 (46 ug/m$^3$).

The data collected at the Dr. Canty residence in Butte also revealed little

Figure 3




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Lincoln School Anaconda
January 1978 - June 1980

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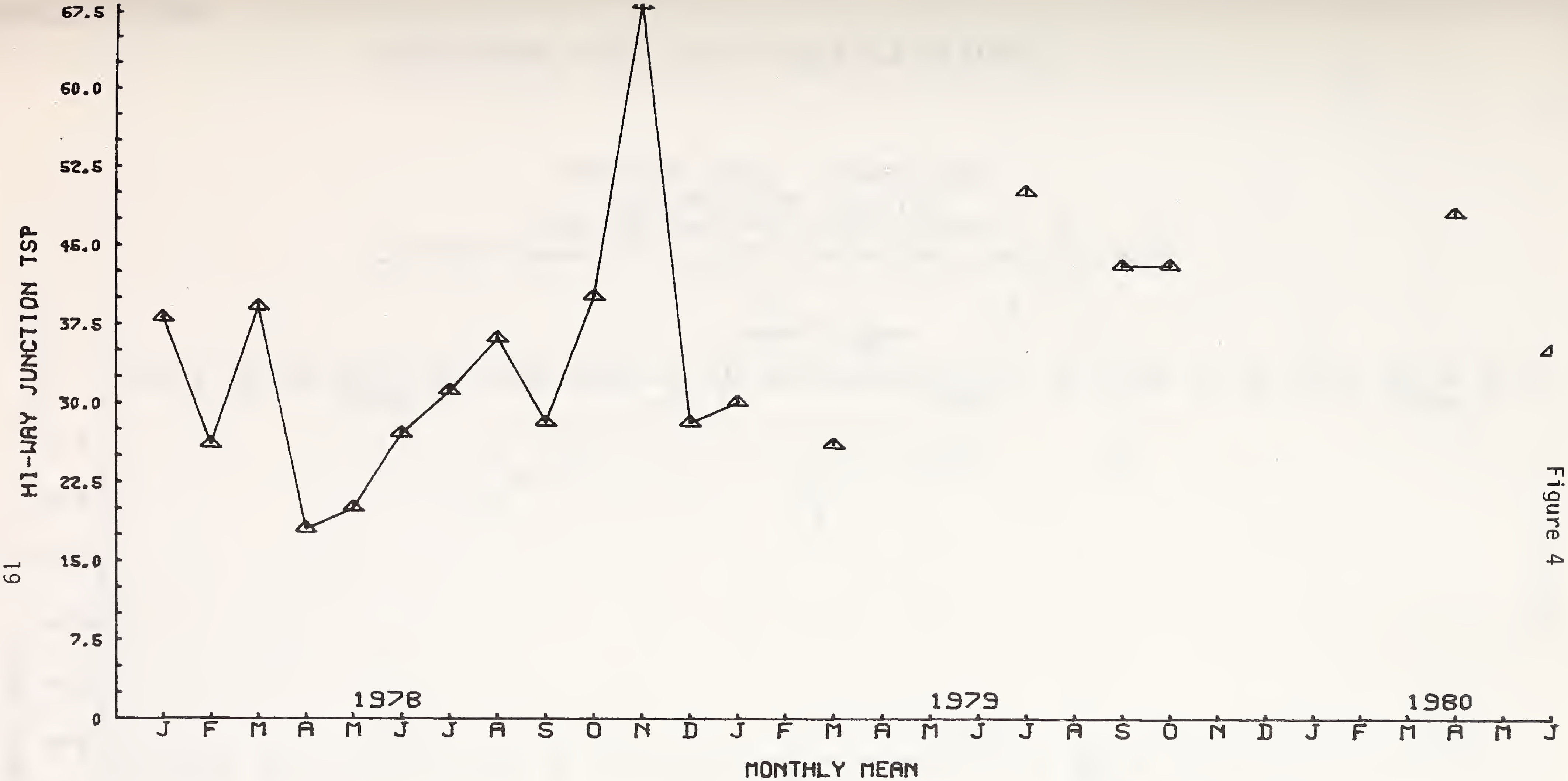
Figure 4




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Hi-way Junction Anaconda
January 1978 - June 1980

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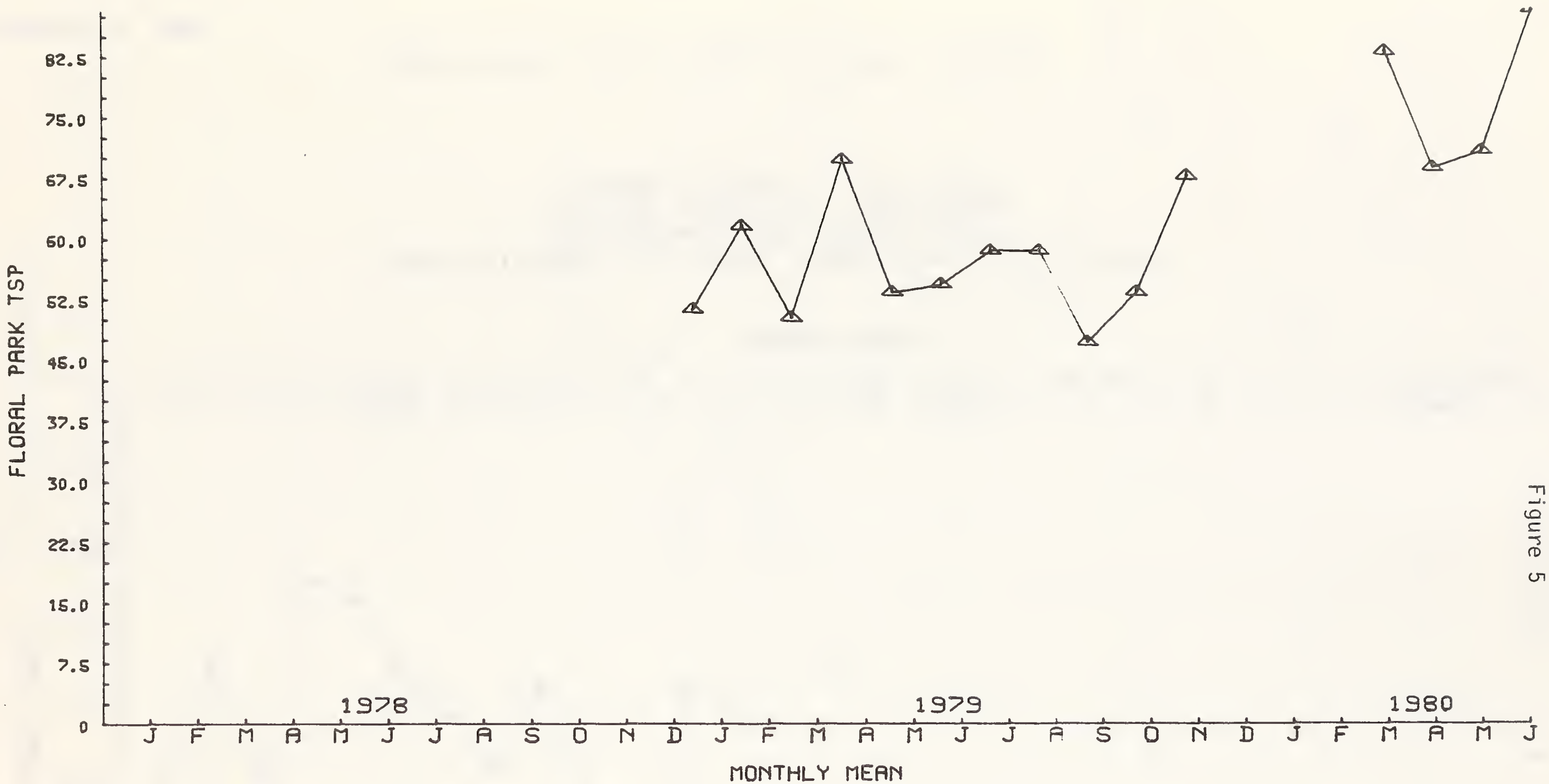
Figure 5




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Floral Park Butte
January 1978 - June 1980

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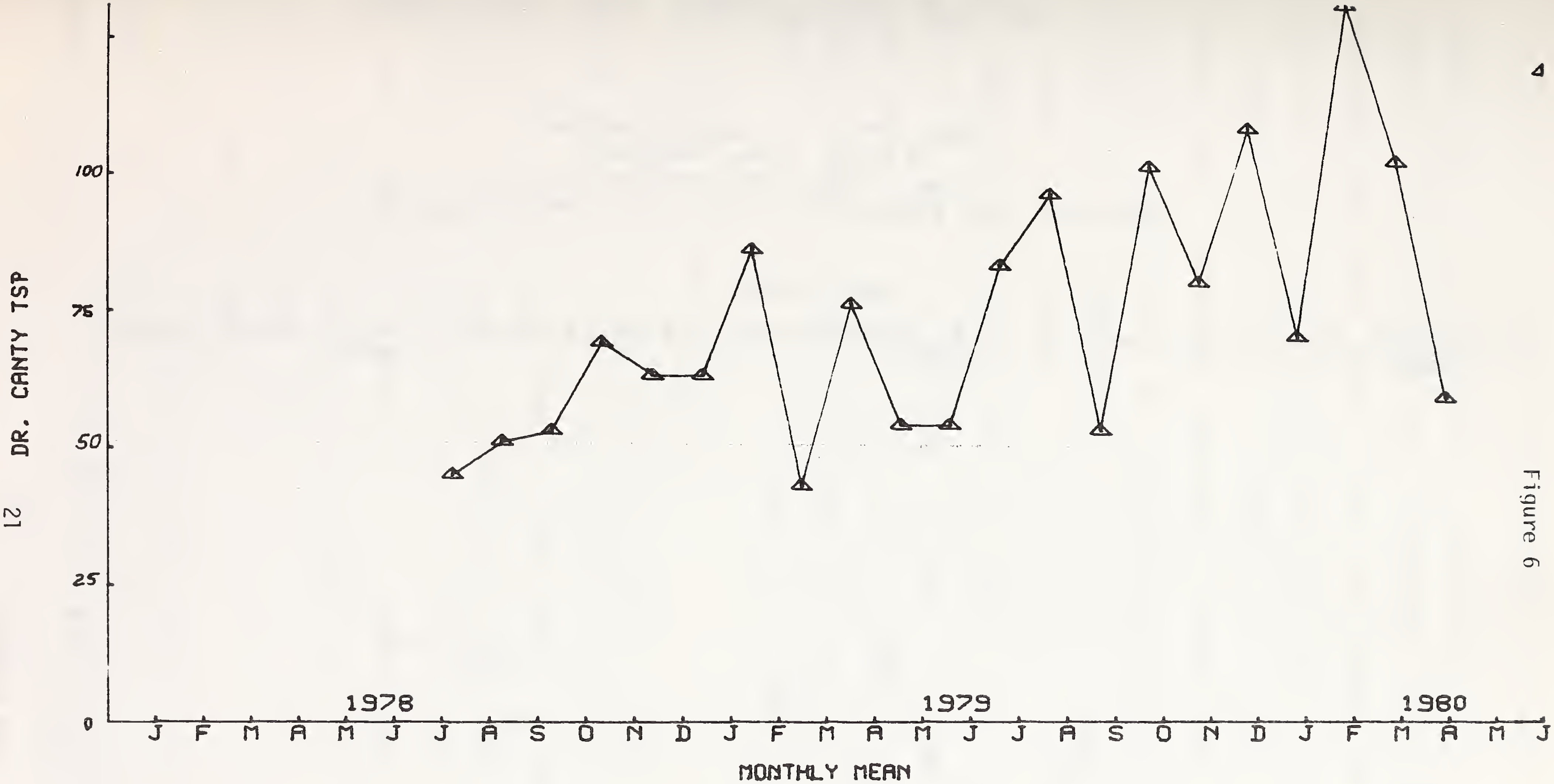
Figure 6




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Dr. Canty Butte
January 1978 - June 1980

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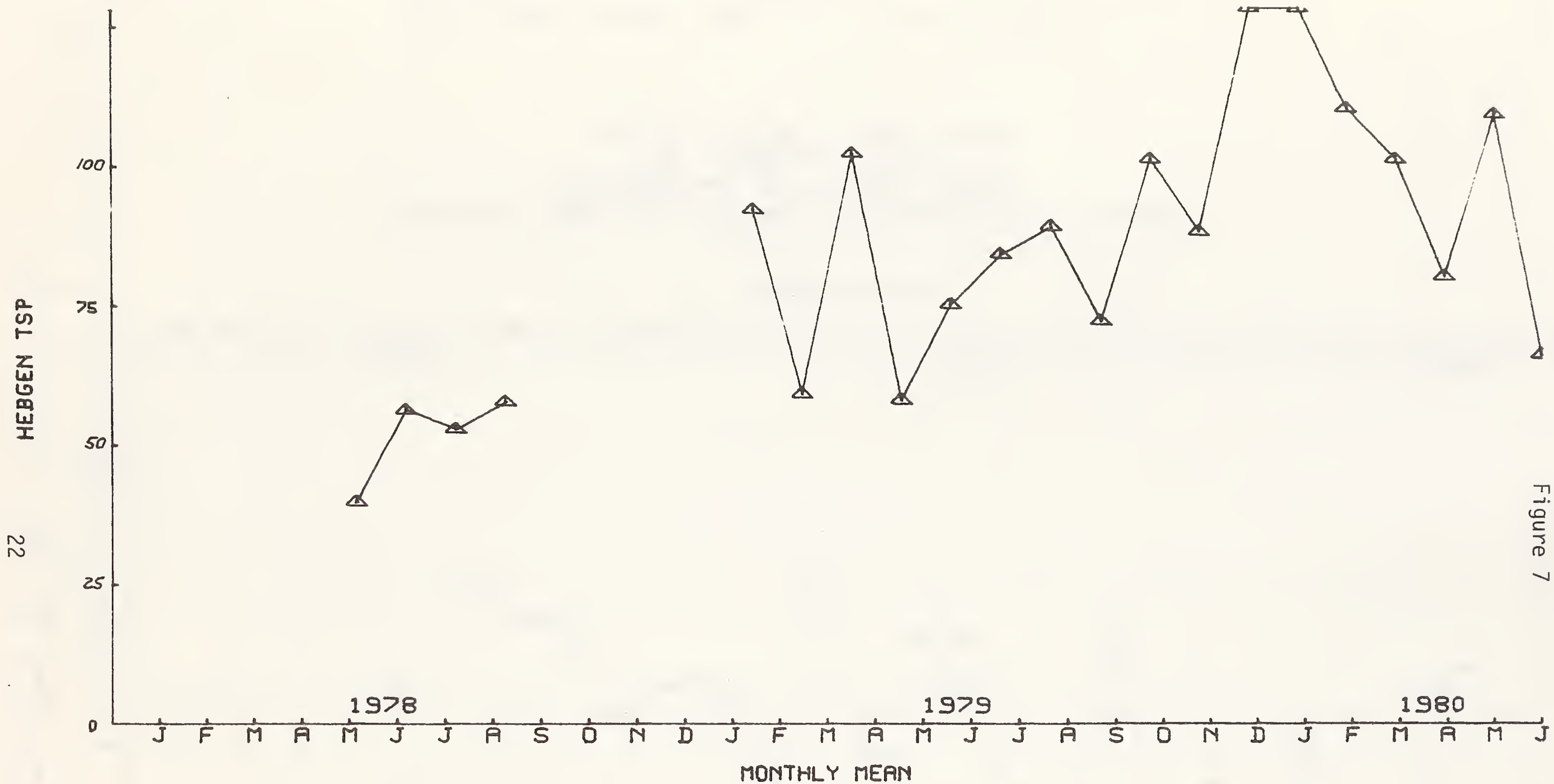
Figure 7




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Hebgen Park Butte
January 1978 - June 1980

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seasonal trend. Variation occurs from month to month. The trend for the two years is toward higher average concentrations as the period progressed (Figure 6). The highest average occurred during January 1980 (131 ug/m$^3$), whereas the lowest average occurred during June 1980 (40 ug/m$^3$).

The Greeley School site data also show a great variation from month to month with the overall trend toward higher concentrations of particulates toward the end of the sampling period. The highest average concentration occurred in November 1979 (197 ug/m$^3$) with the lowest average in February 1980 (38 ug/m$^3$). No seasonal trend is evident from the data presented in Table 5.

Hebgen Park data shown in Table 5 and Figure 7 show a seasonal trend toward higher particulate concentrations during the autumn and winter, with lower concentrations in late spring or early summer. The maximum monthly average occurred in November and December 1979 (128 ug/m$^3$), while the lowest average concentration occurred during May 1978 (40 ug/m$^3$).

2. Inhalable Suspended Particulates

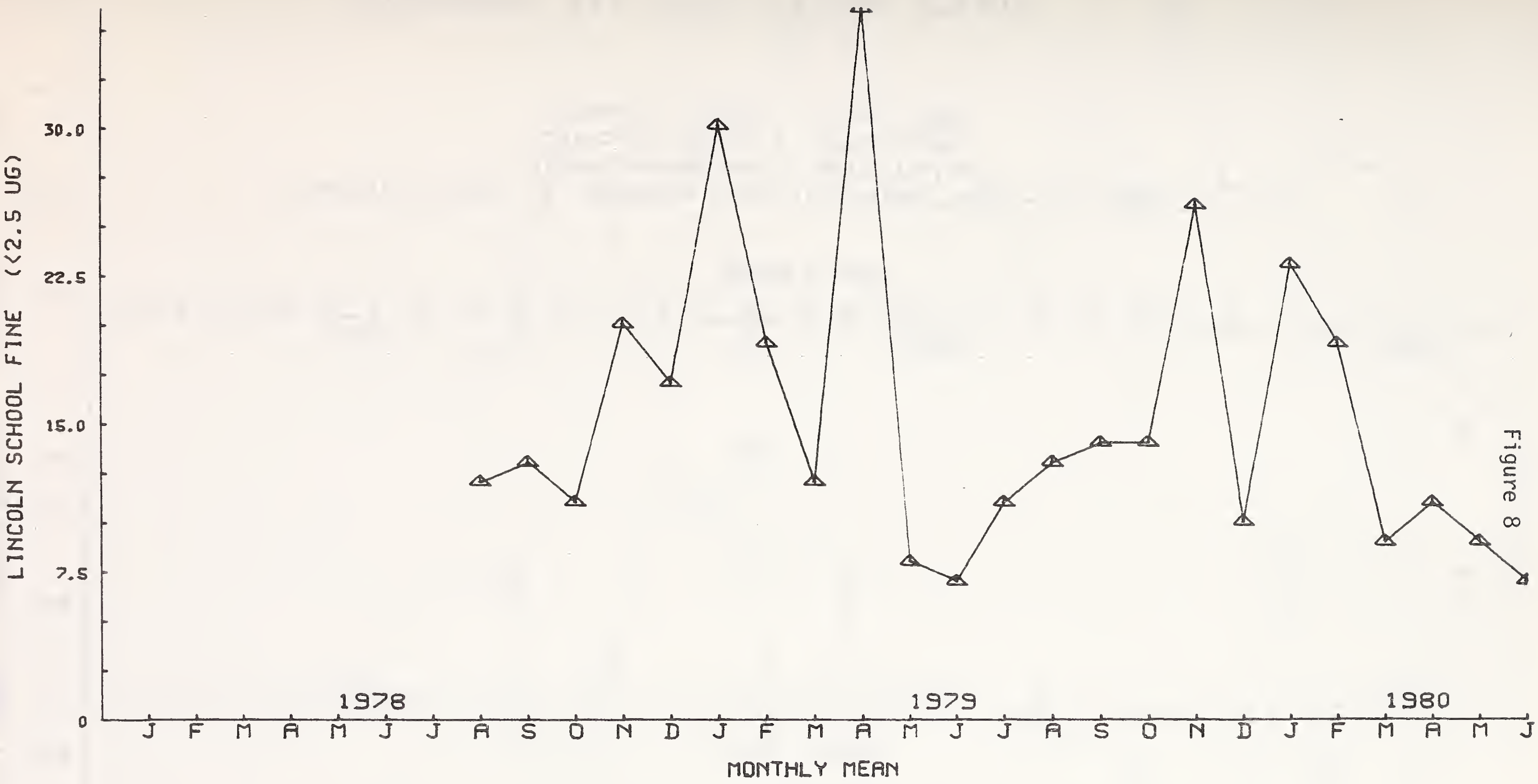
During the MAPS monitoring program, a network of samplers was established throughout the state to measure the concentration of fine suspended particulates. Although no Montana or federal ambient standard exists at this writing for selective sizes of suspended particulates, the MAPS staff felt the collection of data on the concentration of fine particulates to be crucial to the health effects studies. Moreover, since the Environmental Protection Agency (EPA) is contemplating a federal inhalable particulate standard, the MAPS staff felt the data would be very useful in establishing trends once a fine particulate standard is adopted.

The MAPS network of inhalable particulate samplers consisted of a device commonly called a dichotomous air sampler. This sampler operates on the same general principle as the high-volume sampler, except that the dichotomous

sampler rejects large particles using airflow dynamics. The remaining particles become further separated into two size ranges (dichotomous). These sizes are particles less than 2.5 microns in diameter, commonly called fine particulates, and particles from 2.5 to 15 microns in diameter, commonly called coarse particulates. The sum of these two ranges are considered to be inhalable, i.e., these particles can enter the throat through the mouth or nose. The particles less than 2.5 microns are considered respirable or fine in that this size can enter the body's deep lungs. Therefore, a network of dichotomous samplers were established in the MAPS cities. Three samplers were located in the Butte/Anaconda area at Lincoln School, Floral Park, and Hebgen Park.

Table 6 summarizes the monthly average values of the two size ranges, the total fine particulates, and the total suspended particulates as measured by a high-volume sampler at the Lincoln School. The particles less than 2.5 microns show a great deal of variation, varying from a minimum of 7 ug/m$^3$ in June 1979 and June 1980 to a maximum of 36 ug/m$^3$ in April 1979. The overall average concentration of particles less than 2.5 microns is 15 ug/m$^3$. The trend over the two-year period shows lowest concentrations during the late spring and summer and highest concentrations during late autumn and winter. Particles less than 2.5 microns contribute on the average 39 percent of the total fine particulates. The concentration of particles from 2.5 to 15 microns also show significant variation, although not as much as the finer particles. The coarse fraction concentration (particles from 2.5 to 15 microns) varies from a low of 6 ug/m$^3$ in February 1979 to a high of 36 ug/m$^3$ in March 1979. The overall average concentration is 23 ug/m$^3$. The coarse fraction of the total inhalable particulates is about 61 percent. The trend of the concentration of coarse fraction is not as clear as that of the fine fraction, and no seasonal trend appears to dominate. (See figures 8 through 10.)

Figure 8




Monthly Mean vs. Fine Particulate (<2.5 ug/m*3)
Micrograms per Cubic Meter
Lincoln School Anaconda
January 1978 - June 1980

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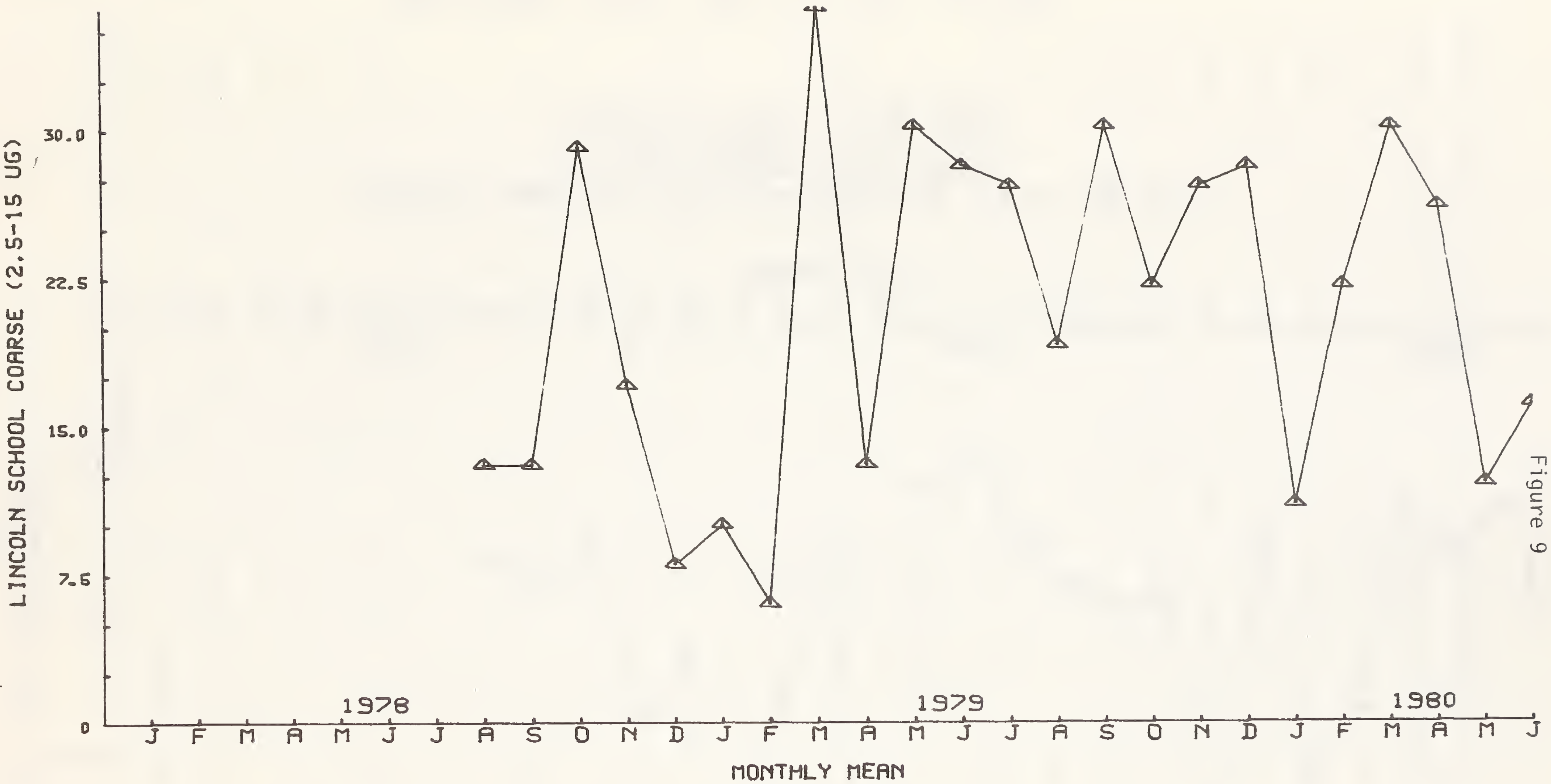
Figure 9




Monthly Mean vs. Coarse Particulate (2.5-15 ug/m*3)
Micrograms per Cubic Meter
Lincoln School Anaconda
January 1978 - June 1980

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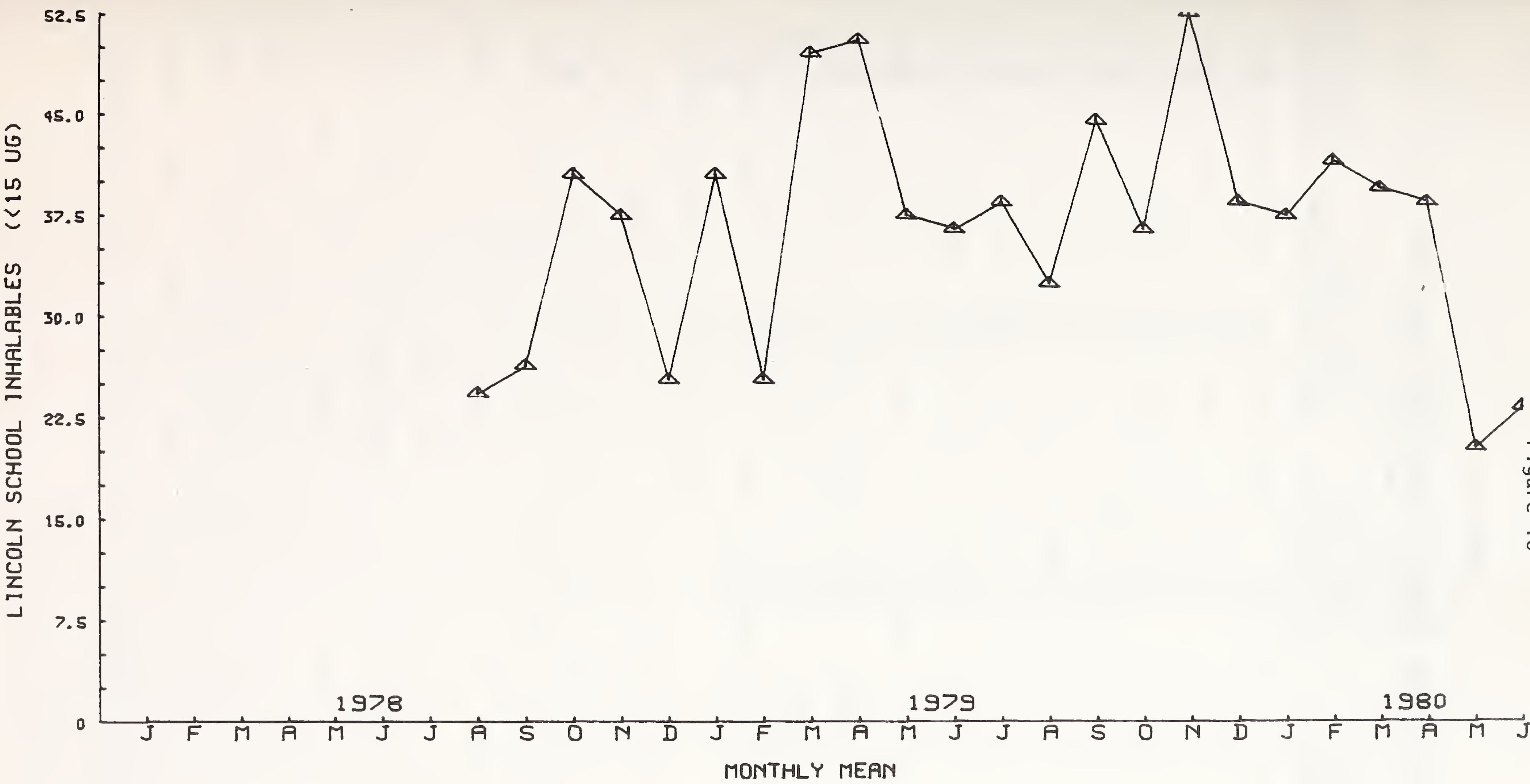
Figure 10




Monthly Mean vs. Inhalable Particulates (<15 ug/m*3)
Micrograms per Cubic Meter
Lincoln School Anaconda
January 1978 - June 1980

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TABLE 6

LINCOLN SCHOOL MONTHLY AVERAGE PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Susp. Particulates | Susp. Part. <2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. <15 microns |
|---|---|---|---|---|
| Aug 78 | 41 | 12 | 13 | 24 |
| Sep | 39 | 13 | 13 | 26 |
| Oct | 55 | 11 | 29 | 40 |
| Nov | 46 | 20 | 17 | 37 |
| Dec | 22 | 17 | 8 | 25 |
| Jan 79 | 39 | 30 | 10 | 40 |
| Feb | 23 | 19 | 6 | 25 |
| Mar | 90 | 12 | 36 | 49 |
| Apr | 40 | 36 | 13 | 50 |
| May | 55 | 8 | 30 | 37 |
| Jun | 47 | 7 | 28 | 36 |
| Jul | 54 | 11 | 27 | 38 |
| Aug | 51 | 13 | 19 | 32 |
| Sep | 90 | 14 | 30 | 44 |
| Oct | 74 | 14 | 22 | 36 |
| Nov | 89 | 26 | 27 | 52 |
| Dec | 53 | 10 | 28 | 38 |
| Jan 80 | 49 | 23 | 11 | 37 |
| Feb | 76 | 19 | 22 | 41 |
| Mar | 60 | 9 | 30 | 39 |
| Apr | 88 | 11 | 26 | 38 |
| May | 42 | 9 | 12 | 20 |
| Jun | 53 | 7 | 16 | 23 |
| Average | 54 | 15 | 23 | 38 |
| Average (Dec 78 - June 80) | 57 | 15 | 23 | 38 |

Table 7 lists the monthly average fine particulate data for the Floral Park site in Butte. The sampler was operated from December 1978 through June 1980. The fine fraction varies from 8 ug/m$^3$ in May 1980 to 40 ug/m$^3$ in January 1979. The seasonal trend shows higher concentrations in the autumn and winter, and lower concentrations in the mid-summer. The overall average concentration of particulates less than 2.5 microns is 18 ug/m$^3$. The contribution to the inhalable particulate concentration averages 50 percent. The concentration of the fine fraction overall is similar at both the Floral Park and Lincoln School sites, with the Floral Park site averaging slightly higher. The coarse fraction at the Floral park site averages from a low of 8 ug/m$^3$ in January 1979 and May 1980 to a high of 26 ug/m$^3$ in April 1980. The overall average is 19 ug/m$^3$. No distinct trend is apparent for the coarse fraction. Comparing the coarse fraction of Floral Park and Lincoln School, Lincoln School averages slightly higher (23 versus 19 ug/m$^3$). Figures 11 through 13 display the monthly average inhalable particulate data for Floral Park. Data points were not plotted if less than four samples were available for the month.

Table 8 summarizes the monthly average inhalable particulate data for the Hebgen Park site in Butte. The fine fraction varies from a low of 11 ug/m$^3$ in June 1979 to a high of 38 ug/m$^3$ in January 1980. The overall average concentration was 20 ug/m$^3$. Figures 14 through 16 and Table 8 show a trend of higher concentrations in the late autumn and winter and lower concentrations in the mid-summer. This trend compares very closely to that of the Lincoln School site. The contribution of the fine fraction to the total fine particulates is about 38 pecent, which also follows very closely the contribution at the Lincoln School site. The coarse fraction varies from a low of 14 ug/m$^3$ in December 1978 and May 1980 to a high of 48 ug/m$^3$ in July 1979 and April 1980. The overall average was 32 ug/m$^3$. No distinct trend is apparent for the coarse fraction,

TABLE 7

FLORAL PARK MONTHLY PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Susp. Particulates | Susp. part. <2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. <15 microns |
|---|---|---|---|---|
| Dec 78 | 50 | 23 | 11 | 34 |
| Jan 79 | 60 | 40 | 8 | 47 |
| Feb | 49 | 18 | 10 | 28 |
| Mar | 68 | 17 | 24 | 41 |
| Apr | 52 | 11 | 24 | 35 |
| May | 53 | 10 | 24 | 35 |
| Jun | 57 | 9 | 24 | 33 |
| Jul | 57 | 13 | 23 | 36 |
| Aug | 46 | 11 | 16 | 27 |
| Sep | 52 | 12 | 22 | 34 |
| Oct | 66 | 26 | 16 | 42 |
| Nov | -- | 27 | 24 | 51 |
| Dec | 117 | --- | --- | --- |
| Jan 80 | 108 | 9 | 24 | 32 |
| Feb | 81 | 28 | 17 | 45 |
| Mar | 67 | 14 | 12 | 27 |
| Apr | 69 | 12 | 26 | 37 |
| May | 86 | 8 | 8 | 17 |
| Jun | 50 | --- | --- | --- |
| Average | 63 | 18 | 19 | 36 |

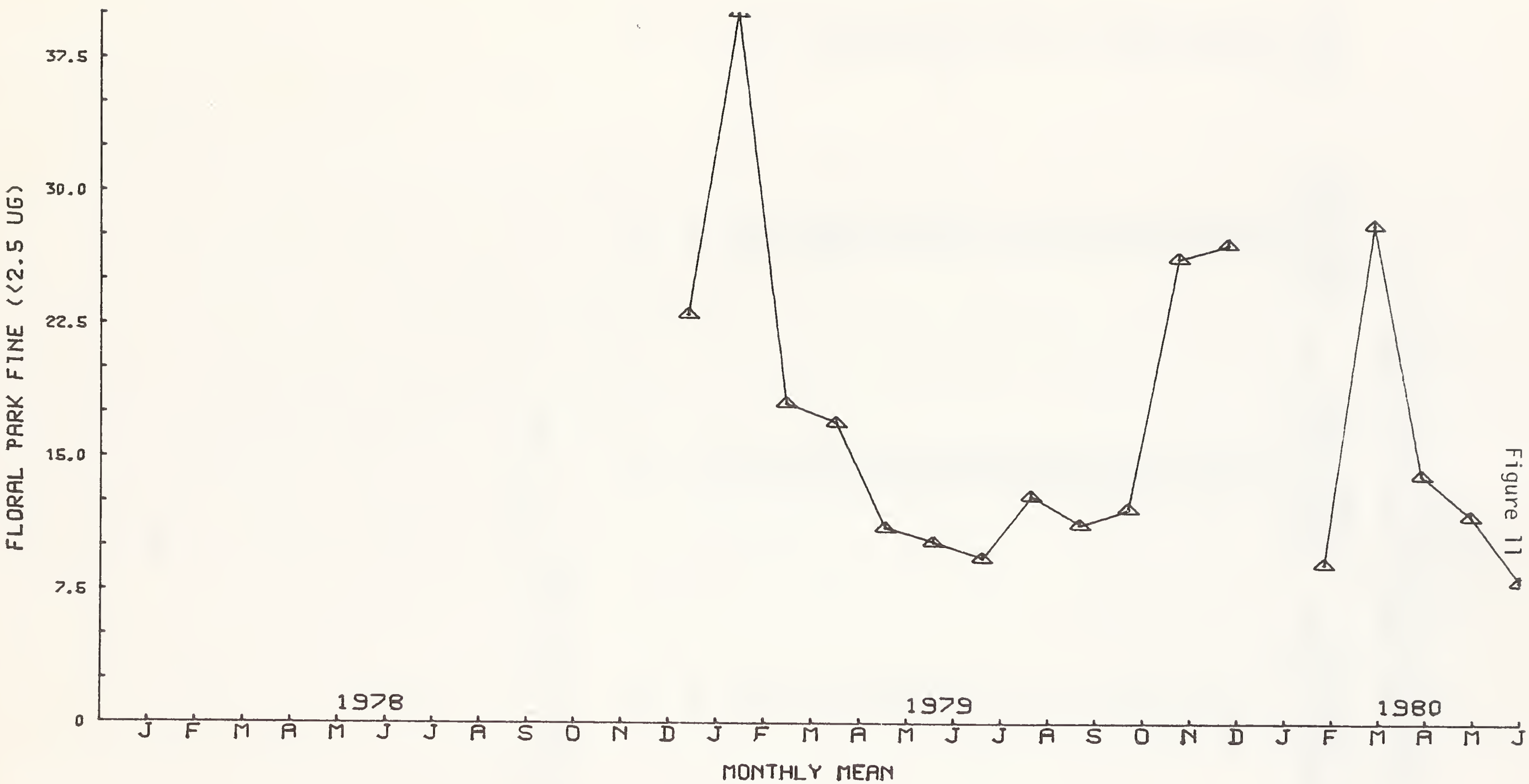
TABLE 8

HEBGEN PARK MONTHLY AVERAGE PARTICULATE DATA

| Month | Total Susp.+ Particulates | Susp. Part.+ <2.5 microns | Susp. Part.+ 2.5 to 15 microns | Susp. Part.+ <15 microns | Scattering* Coeff. |
|---|---|---|---|---|---|
| Oct 78 | 92 | --- | --- | --- | 18.1 |
| Nov | 83 | 24 | 22 | 45 | 32.5 |
| Dec | 69 | 36 | 14 | 50 | 30.4 |
| Jan 79 | 92 | --- | --- | --- | 51.9 |
| Feb | 59 | 29 | 20 | 48 | 22.4 |
| Mar | 102 | 20 | 36 | 56 | 19.9 |
| Apr | 58 | 12 | 36 | 48 | 7.3 |
| May | 75 | 12 | 37 | 49 | 5.8 |
| Jun | 84 | 11 | 36 | 47 | 5.7 |
| Jul | 89 | 16 | 45 | 61 | 7.8 |
| Aug | 72 | 12 | 26 | 37 | 8.3 |
| Sep | 101 | 17 | 34 | 50 | 7.7 |
| Oct | 8 | 23 | 36 | 53 | 10.0 |
| Nov | 128 | 32 | 32 | 64 | 20.8 |
| Dec | 128 | 26 | 31 | 58 | 17.4 |
| Jan 80 | 110 | 38 | 37 | 75 | 22.9 |
| Feb | 101 | 26 | 26 | 53 | 18.7 |
| Mar | 80 | 21 | 25 | 45 | 10.8 |
| Apr | 109 | 21 | 45 | 53 | 7.6 |
| May | 66 | 18 | 14 | 26 | 9.6 |
| Jun | 46 | 13 | 16 | 30 | 4.8 |
| Average | 90 | 20 | 32 | 52 | 16.7 |
| Average (Dec 78 - Jun 80) | 90 | 20 | 33 | 52 | 15.7 |

+Values in micrograms per cubic meter
*Values in scattering coefficient per meter x $10^5$

Figure 11




Monthly Mean vs. Fine Particulate (<2.5 ug/m*3)
Micrograms per Cubic Meter
Floral Park Butte
January 1978 - June 1980

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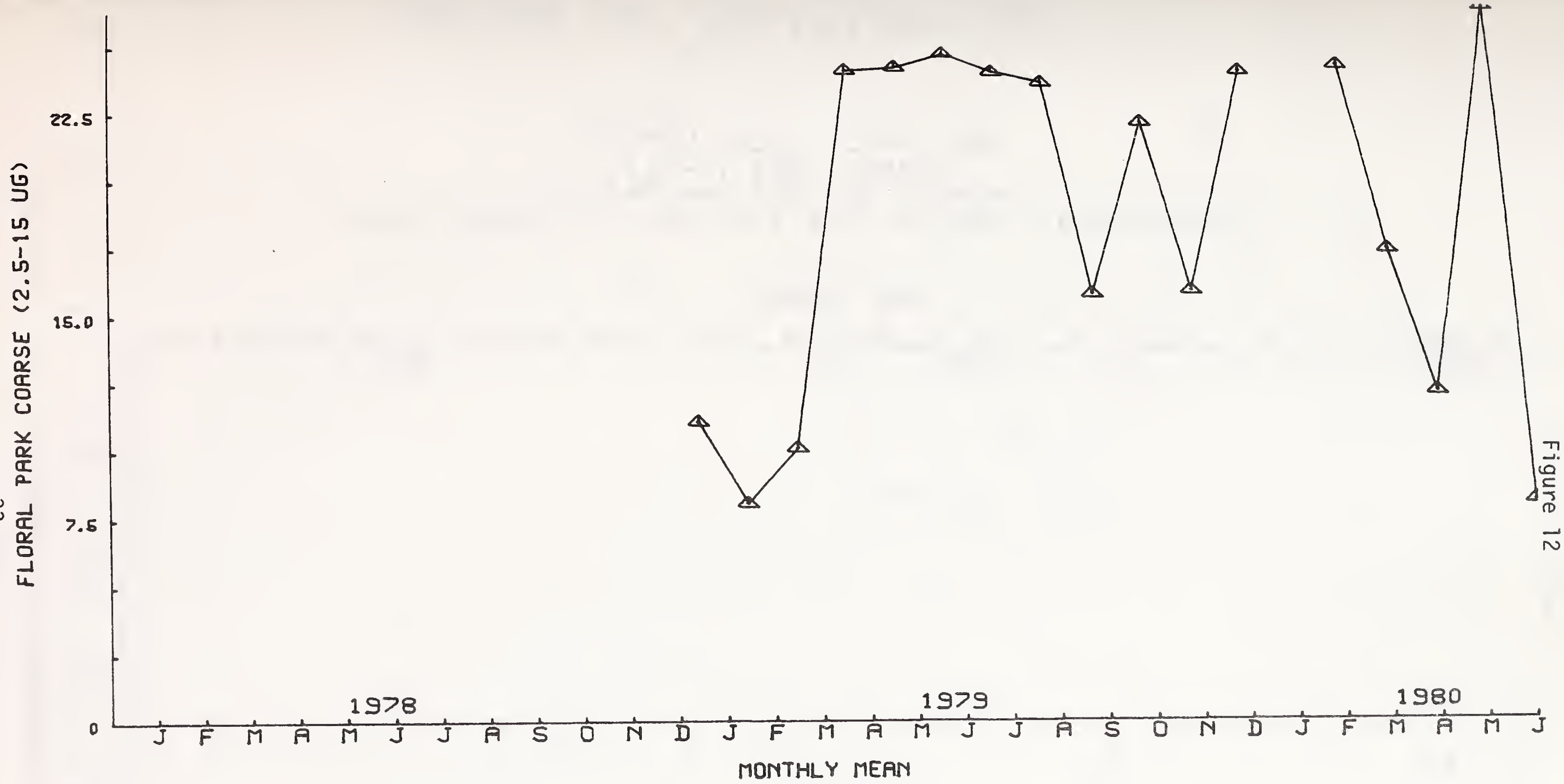
Figure 12




Monthly Mean vs. Coarse Particulate (2.5-15 ug/m*3)
Micrograms per Cubic Meter
Floral Park Butte
January 1978 - June 1980

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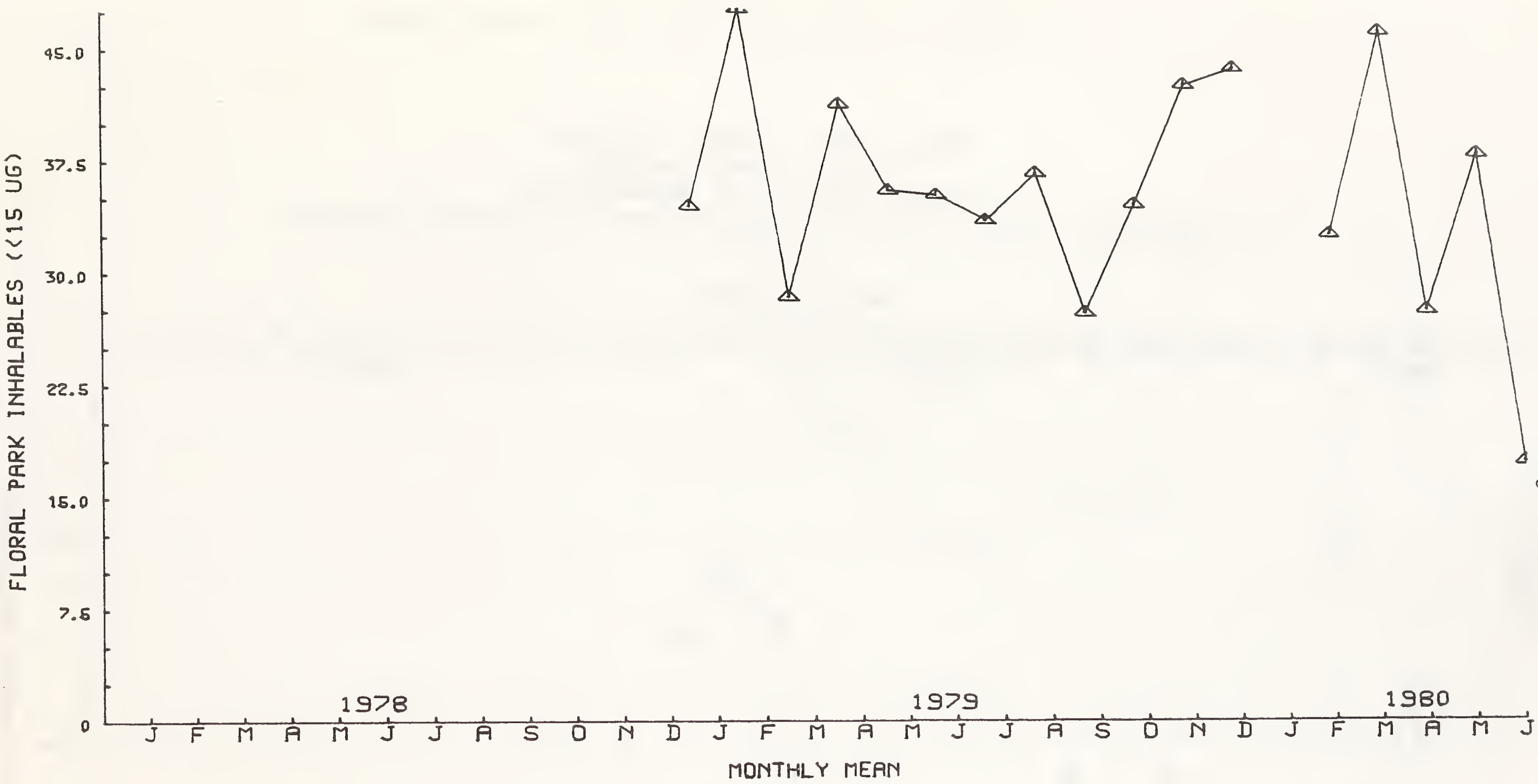
Figure 13




Monthly Mean vs. Inhalable Particulate (<15 ug/m•3)
Micrograms per Cubic Meter
Floral Park Butte
January 1978 - June 1980

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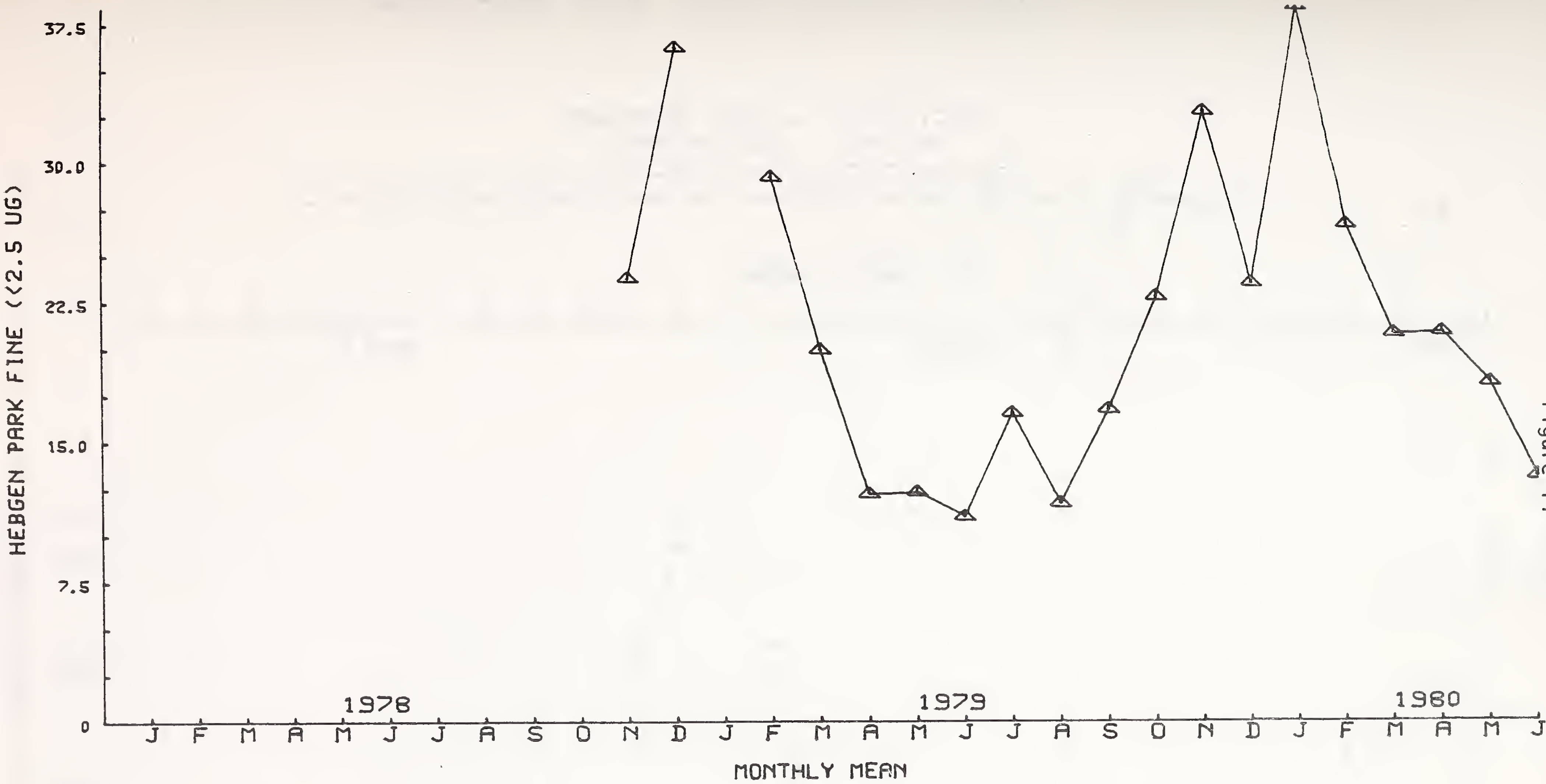
Figure 14




Monthly Mean vs. Fine Particulate (<2.5 ug/m*3)
Micrograms per Cubic Meter
Hebgen Park Butte
January 1978 - June 1980

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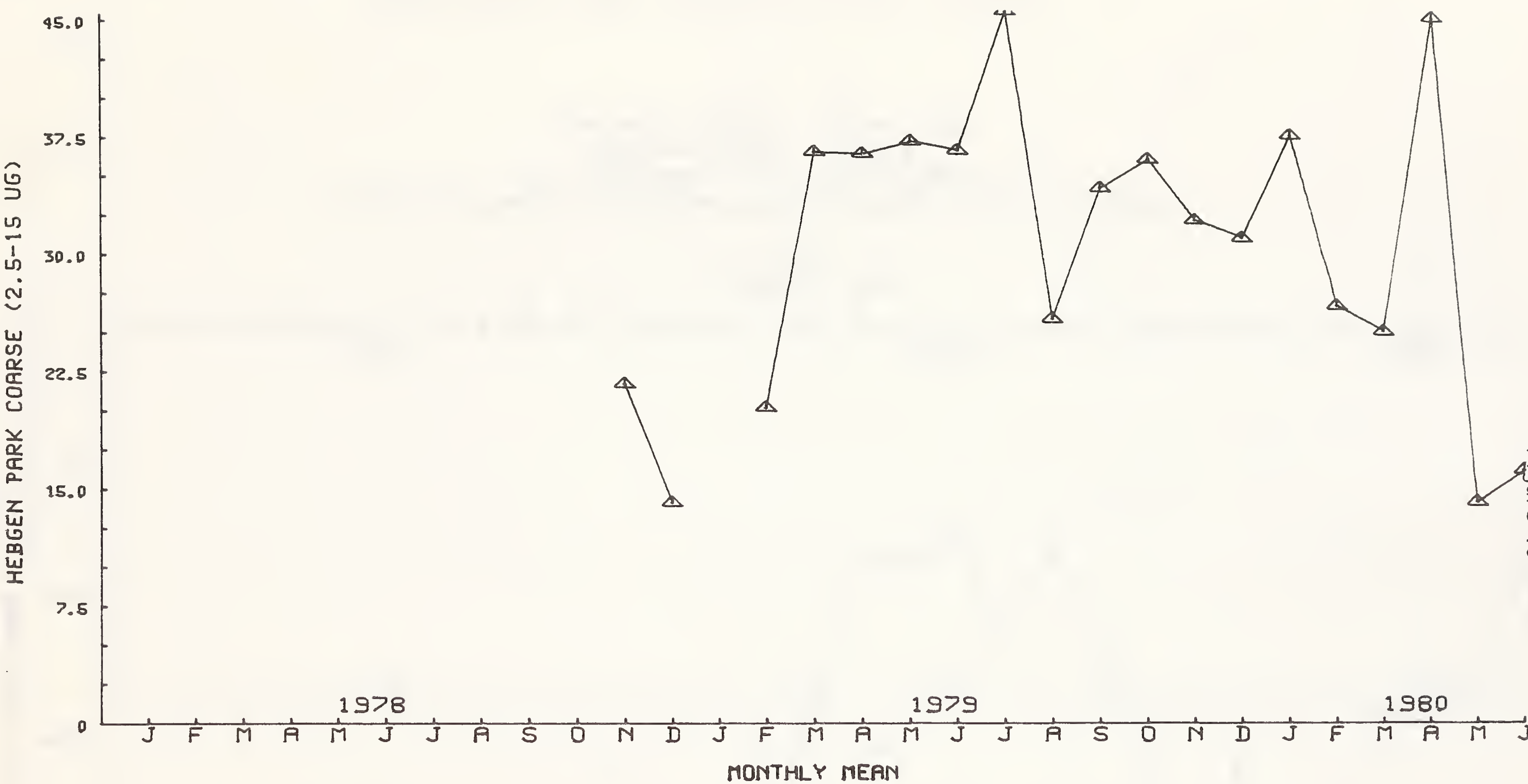
Figure 15




Monthly Mean vs. Coarse Particulate (2.5-15 ug/m•3)
Micrograms per Cubic Meter
Hebgen Park Butte
January 1978 - June 1980

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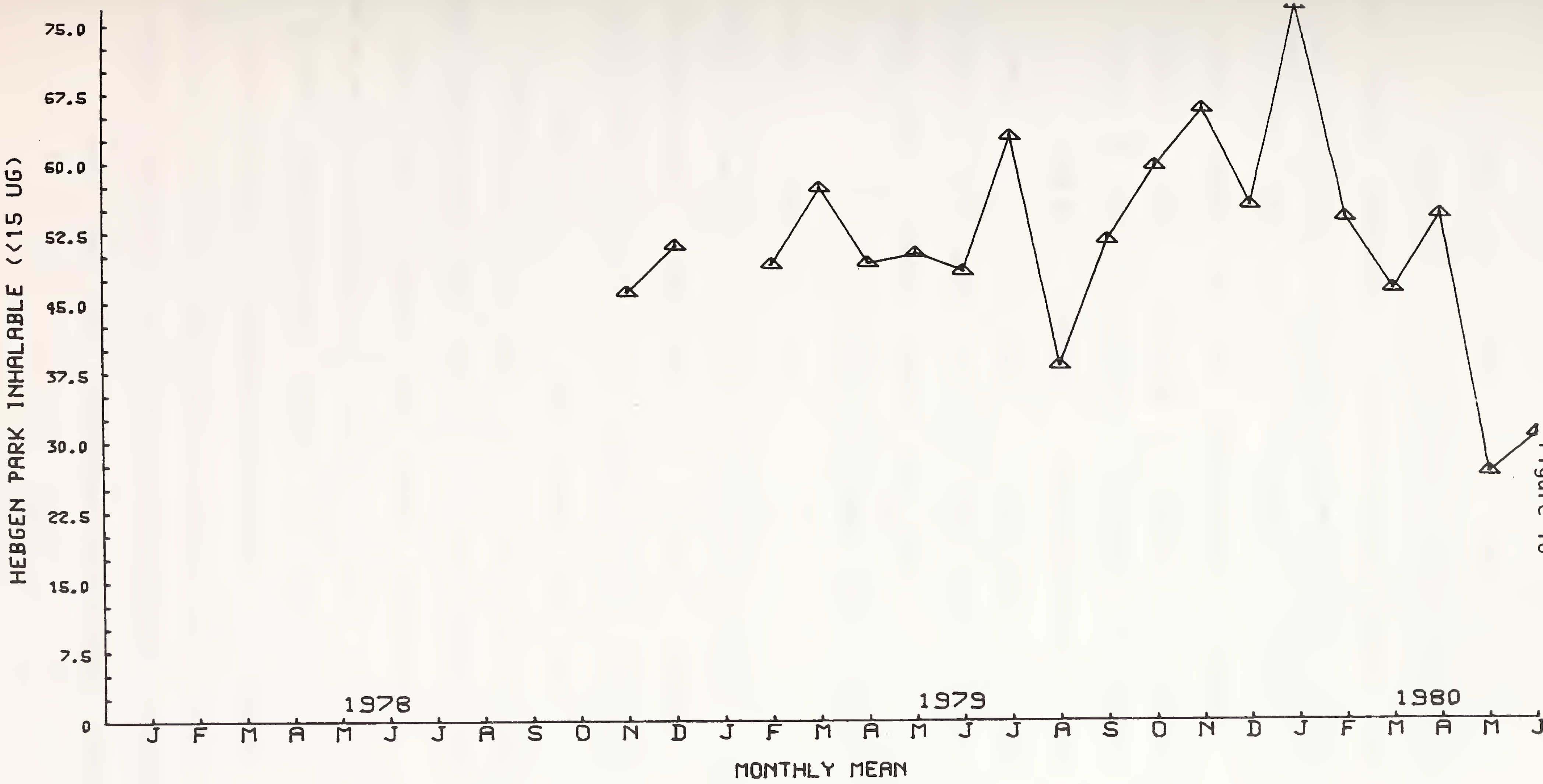
Figure 16




Monthly Mean vs. Inhalable Particulate (<15 ug/m*3)
Micrograms per Cubic Meter
Hebgen Park Butte
January 1978 - June 1980

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as little variation occurred from month to month. Table 8 also shows the monthly average scattering coefficient as measured by an integrating nephelometer. The scattering coefficient is related to the amount of small particles in the air. However, the nephelometer samples the air continuously through the month and gives hourly concentrations. A value of 100 indicates very high concentration of particulates, whereas a low value indicates very clean air. The averages vary from a low of 4.8 (per meter x $10^5$) in June 1980 to a high of 51.9 in January 1979. The overall average was 16.7. The trend follows very closely that of the concentration of particles less than 2.5 microns. This would seem to be reasonable, as the wavelength of light used in the nephelometer is scattered more efficiently by the smaller size particles. Therefore, a high concentration of small particles would scatter a greater percentage of light and result in higher nephelometer readings.

### 3. Trace Elements

During MAPS, chemical analyses were performed on the high-volume air samples for a variety of trace elements by means of atomic absorption. The results of these analyses are presented in Tables 9 through 13. Care must be taken in any analysis of these data. The analysis was performed with only a partial digestion using concentrated nitric acid. Total sampling period arithmetic averages of trace element concentrations at six sites in the Butte/Anaconda area are shown in Table 9. In the tables, values shown as zero are actually less than the detection limit of the analysis method, and therefore, no concentration was detected. In Table 9 the average trace element values are shown, with the corresponding total suspended particulate concentrations for comparison of different sites. For aluminum, the values vary little from site to site, with the exception of the Highway Junction and Hebgen Park sites. The Highway Junction average for aluminum fell significantly below that of the other sites

TABLE 9

BUTTE/ANACONDA AREA AVERAGE TRACE ELEMENT DATA*
(Values in micrograms per cubic meter)

Arithmetic Means

| Element | Lincoln Sch | Hiway Jct | Floral Park | Dr. Canty Res | Greeley Sch | Hebgen Park |
|---|---|---|---|---|---|---|
| Aluminum | 0.47 | 0.20 | 0.52 | 0.57 | 0.52 | 0.97 |
| Arsenic | 0.142 | 0.276 | 0.015 | 0.021 | 0.025 | 0.021 |
| Cadmium | 0.022 | 0.021 | 0.008 | 0.012 | 0.014 | 0.010 |
| Chromium | 0.004 | 0.000 | 0.000 | 0.000 | 0.003 | 0.004 |
| Copper | 0.42 | 0.85 | 0.15 | 0.24 | 0.37 | 0.37 |
| Iron | 0.43 | 0.95 | 0.19 | 0.77 | 1.09 | 1.15 |
| Lead | 0.35 | 0.35 | 0.22 | 0.31 | 0.30 | 0.36 |
| Manganese | 0.03 | 0.03 | 0.04 | 0.06 | 0.07 | 0.07 |
| Nickel | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 |
| Vanadium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Zinc | 0.36 | 0.50 | 0.12 | 0.13 | 0.36 | 0.29 |
| Nitrate | 1.05 | 0.98 | 1.83 | 2.06 | 1.97 | 2.16 |
| Sulfate | 5.17 | 7.8 | 5.26 | 5.51 | 5.69 | 5.24 |
| TSP | 54 | 36 | 63 | 74 | 84 | 83 |

*Data derived from high-volume air sampler filters only

TABLE 10

LINCOLN SCHOOL MONTHLY AVERAGE TRACE ELEMENTS AND PARTICULATE DATA*
(Values in micrograms per cubic meter)

| Month | TSP | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc | Nitrate | Sulfate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul 78 | 41 | 0.26 | 0.127 | 0.017 | 0.013 | 0.47 | 0.48 | 0.37 | 0.02 | --- | --- | 0.30 | 0.7 | 5.8 |
| Aug | 41 | 0.12 | 0.045 | 0.022 | 0.023 | 0.22 | 0.48 | 0.20 | --- | --- | --- | 0.18 | 0.7 | 5.9 |
| Sep | 39 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.6 | 6.1 |
| Oct | 55 | 0.20 | 0.327 | 0.036 | --- | 0.50 | 0.33 | 0.80 | 0.02 | --- | --- | 0.41 | 0.8 | 5.9 |
| Nov | 46 | 0.24 | 0.465 | 0.065 | 0.156 | 0.71 | 0.46 | 0.74 | 0.04 | --- | --- | 0.44 | 1.5 | 6.6 |
| Dec | 22 | 0.09 | 0.114 | 0.025 | 0.100 | 0.34 | 0.18 | 0.37 | 0.12 | --- | --- | 0.23 | 0.9 | 4.1 |
| | | | | | | | | | | | | | | |
| Jan 79 | 39 | 0.10 | 0.275 | 0.028 | 0.021 | 0.92 | 0.36 | 0.59 | 0.01 | 0.005 | --- | 0.57 | 2.6 | 7.4 |
| Feb | 23 | 1.29 | 0.100 | 0.031 | --- | 0.51 | 0.32 | 0.28 | 0.01 | --- | --- | 0.61 | 1.1 | 4.3 |
| Mar | 90 | 3.40 | 0.042 | 0.012 | 0.000 | 0.30 | 0.70 | 0.22 | 0.03 | 0.006 | 0.00 | 0.30 | 1.1 | 4.3 |
| Apr | 40 | --- | 0.021 | 0.002 | 0.000 | 0.10 | --- | 0.09 | 0.02 | 0.002 | 0.00 | --- | 0.9 | 2.0 |
| May | 55 | --- | 0.026 | 0.005 | 0.000 | 0.10 | --- | 0.16 | 0.03 | 0.007 | 0.01 | --- | 0.6 | 3.7 |
| Jun | 47 | --- | 0.041 | 0.009 | 0.000 | 0.29 | --- | 0.18 | 0.03 | 0.018 | 0.00 | --- | 0.7 | 3.7 |
| Jul | 54 | --- | 0.062 | 0.012 | 0.000 | 0.45 | --- | 0.27 | 0.03 | 0.003 | 0.00 | --- | 0.8 | 5.2 |
| Aug | 51 | --- | 0.111 | 0.022 | 0.000 | 0.45 | --- | 0.39 | 0.04 | 0.004 | 0.00 | --- | 0.9 | 6.1 |
| Sep | 90 | --- | 0.123 | 0.023 | 0.000 | 0.52 | --- | 0.37 | 0.05 | 0.001 | 0.00 | --- | 0.8 | 7.3 |
| Oct | 74 | --- | 0.143 | 0.023 | 0.000 | 0.40 | --- | 0.39 | 0.04 | 0.000 | 0.00 | --- | 0.9 | 5.4 |
| Nov | 89 | --- | 0.189 | 0.071 | 0.000 | 0.66 | --- | 0.64 | 0.03 | 0.003 | 0.00 | --- | 1.4 | 5.9 |
| Dec | 53 | --- | 0.034 | 0.007 | 0.000 | 0.18 | --- | 0.13 | 0.02 | 0.000 | 0.00 | --- | 0.6 | 2.3 |
| | | | | | | | | | | | | | | |
| Jan 80 | 49 | --- | 0.034 | 0.008 | 0.000 | 0.23 | --- | 0.16 | 0.02 | 0.000 | 0.00 | --- | 1.3 | 4.3 |
| Feb | 76 | --- | 0.230 | 0.016 | 0.000 | 0.76 | --- | 0.34 | 0.04 | 0.000 | 0.00 | --- | 1.7 | 8.4 |
| Mar | 60 | --- | 0.043 | 0.007 | 0.000 | 0.28 | --- | 0.14 | 0.02 | 0.000 | 0.00 | --- | 0.4 | 4.9 |
| Apr | 88 | --- | 0.103 | 0.010 | 0.000 | 0.38 | --- | 0.14 | 0.04 | 0.000 | 0.00 | --- | 0.9 | 7.8 |

*Collection method - high volume air sampler (glass fiber filters) and atomic absorption analysis
Values presented as zero are actually less than detection limit of the analysis method

TABLE 11

LINCOLN SCHOOL MONTHLY AVERAGE TRACE ELEMENT DATA*
(Values in micrograms per cubic meter)

| Month | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug 78 | 0.07 | 0.103 | 0.015 | --- | 0.29 | 0.32 | 0.32 | 0.01 | --- | --- | 0.26 |
| Sep | 0.10 | 0.064 | 0.009 | --- | 0.10 | 0.21 | 0.10 | --- | --- | --- | 0.07 |
| Oct | 0.21 | 0.103 | 0.019 | --- | 0.14 | 0.39 | 0.24 | 0.01 | --- | --- | 0.17 |
| Nov | 0.24 | 0.400 | 0.046 | --- | 0.53 | 0.39 | 0.59 | 0.01 | --- | --- | 0.45 |
| Dec | 0.08 | 0.115 | 0.018 | --- | 0.18 | 0.18 | 0.25 | 0.01 | --- | --- | 0.23 |
| | | | | | | | | | | | |
| Jan 79 | 0.16 | 0.200 | 0.026 | --- | 0.41 | 0.26 | 0.57 | 0.02 | 0.006 | --- | 0.48 |
| Feb | 0.12 | 0.136 | 0.035 | --- | 0.54 | 0.30 | 0.36 | 0.01 | --- | --- | 0.36 |
| Mar | 0.68 | 0.072 | 0.016 | --- | 0.23 | 0.91 | 0.16 | 0.03 | 0.012 | --- | 0.21 |
| Apr | 0.39 | 0.023 | 0.005 | --- | 0.06 | 0.36 | 0.07 | 0.02 | --- | --- | 0.14 |
| May | 0.78 | 0.040 | 0.011 | --- | 0.13 | 0.71 | 0.18 | 0.03 | 0.026 | --- | 0.15 |
| Jun | 0.60 | 0.033 | 0.019 | --- | 0.47 | 0.75 | 0.33 | --- | 0.047 | --- | 0.24 |
| Jul | 0.79 | 0.115 | 0.022 | --- | 0.29 | 0.89 | 0.32 | --- | --- | 000 | 0.31 |
| Aug | 0.49 | 0.178 | 0.039 | --- | 0.41 | 0.58 | 0.61 | --- | 0.026 | 000 | 0.63 |
| Sep | 0.43 | 0.080 | 0.025 | --- | 0.21 | 0.50 | 0.32 | --- | --- | --- | 0.50 |
| Oct | --- | --- | --- | | --- | --- | --- | | | | |
| Nov+ | 1.39 | 0.145 | 0.026 | 0.000 | 0.69 | 1.53 | 0.56 | 0.05 | 0.028 | 0.000 | 0.59 |
| Dec | 0.36 | 0.009 | 0.001 | 0.000 | 0.06 | 0.31 | 0.09 | 0.02 | 0.002 | 0.00 | 0.006 |
| | | | | | | | | | | | |
| Jan 80 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Feb+ | 1.09 | 0.104 | 0.012 | 0.000 | 0.38 | 1.17 | 0.41 | 0.04 | 0.000 | 0.00 | 0.37 |
| Mar | 0.41 | 0.059 | 0.004 | 0.000 | 0.16 | 0.44 | 0.17 | 0.02 | 0.000 | 0.00 | 0.16 |
| Apr | 0.76 | 0.124 | 0.011 | 0.000 | 0.41 | 0.80 | 0.19 | 0.004 | 0.001 | 0.00 | 0.17 |

+Only one sample analyzed
*Collection method - membrane air sampler (flurocarbon-based filter) and atomic absorption analysis

TABLE 12

HEBGEN PARK MONTHLY AVERAGE TRACE ELEMENT AND PARTICULATE DATA*
(Values in micrograms per cubic meter)

| Month | TSP | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc | Nitrate | Sulfate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jun 78 | 56 | 0.98 | 0.005 | 0.002 | 0.014 | 0.13 | 0.92 | 0.17 | 0.05 | --- | | 0.18 | --- | --- |
| Jul | 53 | 0.56 | 0.009 | 0.003 | 0.025 | 0.18 | 1.08 | 0.24 | 0.05 | --- | | 0.13 | 1.6 | 4.0 |
| Aug | 58 | 0.58 | 0.012 | 0.004 | 0.013 | 0.20 | 1.13 | 0.26 | 0.06 | --- | | 0.13 | 1.5 | 4.9 |
| Sep | 59 | 1.70 | 0.006 | 0.005 | --- | 0.13 | 1.66 | 0.44 | 0.07 | --- | | 0.13 | 1.1 | 4.9 |
| Oct | 92 | 1.86 | 0.033 | 0.011 | 0.016 | 0.28 | 2.05 | 0.59 | 0.10 | --- | | 0.24 | 1.7 | 5.7 |
| Nov | 83 | 0.78 | 0.042 | 0.052 | 0.075 | 0.26 | 1.21 | 0.65 | 0.09 | --- | | 0.20 | 2.5 | 5.8 |
| Dec | 69 | 0.40 | 0.051 | 0.013 | 0.011 | 0.23 | 0.66 | 0.62 | 0.04 | --- | | 0.14 | 2.5 | 5.9 |
| Jan 79 | 92 | 0.37 | 0.042 | 0.013 | --- | 0.20 | 0.71 | 0.56 | 0.03 | --- | --- | 2.26 | 4.4 | 6.2 |
| Feb | 59 | 1.53 | 0.008 | 0.005 | 0.002 | 0.21 | 0.74 | 0.56 | 0.04 | 0.000 | 0.00 | 0.13 | 3.0 | 5.7 |
| Mar | 102 | 5.30 | 0.013 | 0.011 | 0.004 | 0.14 | 2.24 | 0.19 | 0.06 | 0.006 | 0.00 | 0.41 | 0.8 | 5.1 |
| Apr | 58 | --- | 0.011 | 0.005 | 0.000 | 0.19 | --- | 0.15 | 0.04 | 0.002 | 0.00 | --- | 1.4 | 3.5 |
| May | 75 | --- | 0.021 | 0.007 | 0.000 | 0.24 | --- | 0.22 | 0.08 | 0.007 | 0.00 | --- | 1.3 | 4.2 |
| Jun | 84 | --- | 0.012 | 0.005 | 0.002 | 0.25 | --- | 0.19 | 0.11 | 0.002 | 0.00 | --- | 1.3 | 3.9 |
| Jul | 89 | --- | 0.013 | 0.007 | 0.000 | 0.29 | --- | 0.19 | 0.11 | 0.028 | 0.00 | --- | 1.5 | 4.3 |
| Aug | 72 | --- | 0.013 | 0.003 | 0.000 | 0.29 | --- | 0.25 | 0.10 | 0.005 | 0.00 | --- | 1.7 | 4.7 |
| Sep | 101 | --- | 0.015 | 0.005 | 0.000 | 0.47 | --- | 0.40 | 0.16 | 0.00 | 0.00 | --- | 2.0 | 6.2 |
| Oct | 88 | --- | 0.060 | 0.007 | 0.002 | 0.25 | --- | 0.35 | 0.08 | 0.001 | 0.00 | --- | 1.5 | 5.0 |
| Nov | 128 | --- | 0.033 | 0.011 | 0.000 | 0.37 | --- | 0.47 | 0.11 | 0.007 | 0.00 | --- | 2.8 | 6.3 |
| Dec | 128 | --- | 0.010 | 0.004 | 0.000 | 0.25 | --- | 0.57 | 0.11 | 0.003 | 0.00 | --- | 1.9 | 4.5 |
| Jan 80 | 110 | --- | 0.015 | 0.007 | 0.000 | 0.27 | --- | 0.34 | 0.07 | 0.000 | 0.00 | --- | 3.1 | 5.9 |
| Feb | 101 | --- | 0.023 | 0.011 | 0.000 | 0.24 | --- | 0.37 | 0.07 | 0.000 | 0.00 | --- | 3.9 | 6.3 |
| Mar | 80 | --- | 0.018 | 0.016 | 0.000 | 0.18 | --- | 0.22 | 0.06 | 0.000 | 0.00 | --- | 1.4 | 5.4 |
| Apr | 109 | --- | 0.016 | 0.006 | 0.000 | 0.26 | --- | 0.15 | 0.12 | 0.000 | 0.00 | --- | 1.7 | 5.9 |

*Collection method - high-volume air sampler (glass fiber filter) and atomic absorption analysis
Values presented as zero are actually less than detection limit of the analysis method

TABLE 13

HEBCEN PARK MONTHLY AVERAGE TRACE ELEMENT DATA

| Month | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec 78 | 1.08 | 0.070 | 0.010 | --- | 0.18 | 1.00 | 0.91 | 0.04 | --- | --- | 0.21 |
| Jan 79 | 0.94 | 0.034 | 0.018 | 0.017 | 0.23 | 1.00 | 0.79 | 0.05 | 0.012 | --- | 0.24 |
| Feb | 1.11 | 0.009 | 0.013 | --- | 0.13 | 1.01 | 0.55 | 0.06 | 0.010 | --- | 0.15 |
| Mar | 1.44 | 0.012 | 0.012 | --- | 0.12 | 1.61 | 0.39 | 0.09 | 0.007 | --- | 0.17 |
| Apr | 0.99 | 0.007 | 0.006 | 0.021 | 0.22 | 1.17 | 0.26 | 0.08 | 0.011 | --- | 0.13 |
| May | 1.13 | 0.019 | 0.005 | --- | 0.16 | 1.39 | 0.27 | 0.09 | 0.007 | --- | 0.16 |
| Jun | 1.10 | 0.010 | 0.003 | --- | 0.16 | 1.33 | 0.24 | 0.08 | 0.014 | --- | 0.14 |
| Jul | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Aug | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sep | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Oct | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Nov | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Dec | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Jan 80 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Feb | 2.35 | 0.006 | 0.000 | 0.000 | 0.20 | 2.29 | 0.49 | 0.12 | 0.000 | 0.00 | 0.19 |
| Mar | 1.12 | 0.016 | 0.013 | 0.000 | 0.13 | 1.21 | 0.28 | 0.06 | 0.000 | 0.00 | 0.17 |
| Apr | 2.50 | 0.008 | 0.005 | 0.000 | 0.23 | 2.47 | 0.25 | 0.13 | 0.000 | 0.00 | 0.19 |

*Collection Method - membrane air sampler (fluorocarbon-based filter and atomic absorption analysis

($0.20 \, ug/m^3$ versus about $0.52 \, ug/m^3$ for the other sites). The Hebgen Park data showed higher than average aluminum values, with an average of 0.97. Arsenic values revealed a much greater variation from site to site. The low average was recorded at the Floral Park site ($0.015 \, ug/m^3$), whereas the high average was recorded at the Highway Junction site ($0.276 \, ug/m^3$). The two Anaconda sites had averages about ten times as high as the Butte area sites for arsenic. The Butte area sites showed little variation of arsenic values. Cadmium averages showed much less variation from site to site, with the low average recorded at the Floral Park site ($0.008 \, ug/m^3$) versus a high of 0.022 recorded at the Lincoln School site. Generally, the Anaconda sites averaged about twice that recorded at the Butte sites. Chromium was never detected in any significant concentration, and in most cases, was below the detection limit. Copper values, on the other hand, were detected at all sites, with a low of $0.15 \, ug/m^3$ recorded at the Floral Park site, and a high of $0.85 \, ug/m^3$ recorded at the Highway Junction site. Generally, the Anaconda sites had averages slightly higher than the Butte sites. Likewise, in Butte, as the distance from the copper mine increased, the average copper concentration decreased. Iron averages also showed a great deal of variation, with a low average of 0.19 $ug/m^3$ recorded at the Floral Park station to a high of $1.15 \, ug/m^3$ recorded at Hebgen Park. Again, in Butte, as the distance from the copper mine increased, the iron concentration decreased. Lead values, however, showed very little variation, with an average of about $0.31 \, ug/m^3$. This value compares with the Montana and federal standard for lead of $1.5 \, ug/m^3$, ninety-day average and quarter average, respectively. All stations had concentrations of lead well below the ambient standards. Manganese, nickel, and vanadium all showed very low concentrations at all sites. Zinc values varied from a low of $0.12 \, ug/m^3$

at the Floral Park station to a high of 0.50 ug/m$^3$ at the Highway Junction station. Nitrate averages ranged from a high of 2.16 ug/m$^3$ at Hebgen park to a low of 0.98 ug/m$^3$ at Highway Junction. Sulfate averages showed very little variation at all sites (about 5.2 ug/m$^3$) except for the Highway Junction site (7.8 ug/m$^3$).

Table 10 lists the monthly averages of the trace element data at the Lincoln School site. The data are presented primarily to show the trends of the various trace elements. Arsenic values show highest values during the autumn, with the lowest values occurring during the late spring and early summer. Concentrations ranged from 0.021 ug/m$^3$ in April 1979 to 0.465 in November 1978. Cadmium concentrations revealed similar trends to those of arsenic, with lowest values in late spring and early summer and highest values in the autumn. Concentrations varied from 0.002 ug/m$^3$ in April 1979 to 0.071 ug/m$^3$ in November 1979. Copper concentrations also showed the same trend, varying from a low of 0.10 ug/m$^3$ in April 1979 to a high of 0.92 ug/m$^3$ in January 1979. Lead concentrations followed the same trend, with a low of 0.09 ug/m$^3$ in April 1979 to a high of 0.80 ug/m$^3$ in October 1978. Nitrate and sulfate concentrations varied somewhat from the previous trend of the other trace elements. Highest concentration occurred generally in mid-winter, with lowest concentrations occurring in the summer.

At the Lincoln School site, sampling also was conducted for trace elements using a membrane sampler and fluorocarbon-based filters. Analysis was performed on the membrane samples for similar trace elements, the results of which are presented as monthly averages in Table 11. Arsenic concentrations from the membrane sampler were very similar to those of the high-volume sampler. The same was true for cadmium. However, differences in copper and lead values

varied greatly between the high-volume samples and the membrane samples. No trend was evident as to which direction the difference tended to move.

Hebgen Park site also was equipped with a high-volume air sampler and a membrane air sampler. Samples from these instruments were analyzed for similar trace elements as were those at the Lincoln School site. The results for Hebgen Park are presented in Tables 12 and 13. The values shown are monthly averages in ug/$m^3$. Aluminum values from the high volume sampler ranged from 0.37 ug/$m^3$ in January 1979 to 5.30 ug/$m^3$ in March 1979. No clear seasonal trend was evident. However, only nine months of aluminum data were collected. Arsenic values ranged from 0.005 ug/$m^3$ in June 1978 to 0.060 ug/$m^3$ in October 1979. Seasonal trends indicated that highest averages occurred during the autumn, with lowest averages in late spring and summer. Cadmium values ranged from 0.002 ug/$m^3$ in June 1978 to 0.052 ug/$m^3$ in November 1978. Seasonal trends tended slightly toward highest averages in the autumn and lowest averages in the summer. However, no great variation occurred from month to month. Copper and lead values showed the same seasonal trend, with highest values in the autumn and lowest in the summer. Copper averages ranged from 0.1 ug/$m^3$ in June 1978 and September 1978 to 0.47 ug/$m^3$ in September 1979. Lead values ranged from 0.15 ug/$m^3$ in April 1979 and April 1980 to 0.65 ug/$m^3$ in November 1978. Manganese and nickel did not show as clear a seasonal trend. Manganese averages varied from month to month, ranging from 0.03 ug/$m^3$ in January 1979 to 0.16 ug/$m^3$ in September 1979. Nickel varied from 0.000 ug/$m^3$ (below detection limit) during several months to 0.028 ug/$m^3$ in July 1979. The seasonal trend for nitrate and sulfate at Hebgen Park shifted to a maximum during the winter and the minimum during the early summer. Nitrate averages varied from 0.8 ug/$m^3$ in March 1979 to 4.4 ug/$m^3$ in January 1979. Sulfate averages varied from 3.5 ug/$m^3$ in April 1979 to 6.3 ug/$m^3$ in November 1979 and February 1980. In Table 13 the membrane air sampler results for Hebgen Park showed fairly similar

results to those of the high-volume air sampler. Monthly differences between the two samplers were small in most cases. No trend in the differences between the samplers was evident. A comparison of the trace element values at the Lincoln School site with those at the Hebgen Park site revealed that aluminum, iron, manganese, and nitrate were slightly higher at Hebgen Park in Butte, whereas arsenic, cadmium, copper, nickel, zinc, and sulfates were higher at Lincoln School in Anaconda. Lead values were similar at the two sites.

4. Gaseous Pollutants

Sampling was conducted for a variety of gaseous compounds at various locations in the Butte/Anaconda area. Results of this sampling are presented in Tables 14 through 20.

Table 14 summarizes the ozone data collected at the Lincoln School and Hebgen Park sites. Sampling at the Lincoln School site was conducted for about eighteen months during MAPS. The maximum one-hour average concentration recorded was 0.082 parts per million (ppm), which compares to the federal primary one-hour standard of 0.12 ppm, not to be exceeded more than one day per year. The Montana one-hour standard is 0.10 ppm, not to be exceeded more than once per year. Since both the Montana and federal standards allow at least one excursion (since the federal standard allows one day of excursions, hypothetically more than one excursion could be allowed), Table 14 also lists the second highest one-hour ozone concentrations. At Lincoln School the second highest one-hour concentration was 0.070 ppm. This value falls below both the federal and Montana ambient standards. The average ozone concentration at the Lincoln School site for seventeen months was 0.031 ppm.

TABLE 14

BUTTE/ANACONDA AREA OZONE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Lincoln School (Dec 78 - Apr 80) | Hebgen Park (Apr 78 - Jun 80) |
|---|---|---|
| 1-hour maximum (high) | 0.082 | 0.117 |
| 1-hour maximum (2nd high) | 0.070 | 0.099 |
| Average* | 0.031 | 0.021 |
| No. of Readings | 8853 | 16,926 |

*Time period of average varies by site

TABLE 15

BUTTE/ANACONDA AREA CARBON MONOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Alpine West (Jan 78 - Aug 79) | Hebgen Park (Jul 78-Nov 78, Sep 79-Nov 79) |
|---|---|---|
| 1-hour maximum | 16.0 | 15.5 |
| 8-hour maximum | 8.4 | 7.8 |
| Average* | 1.0 | 0.9 |
| No. of Readings | 12,764 | 3,313 |

*Time period of average varies by site

TABLE 16

BUTTE/ANACONDA AREA HYDROCARBON DATA SUMMARY[a]
(Values in parts per million)

| Averaging Time | Total Hydrocarbons Lincoln School (Jan, Jun-Nov 79) | Total Hydrocarbons Hebgen Park (Mar - Nov 78) | Methane Hydrocarbons Hebgen Park (Jul-Nov 78) |
|---|---|---|---|
| 3-hour maximum (high)* | 3.2 | 4.8 | 1.9[b] |
| 3-hour maximum (2nd high)* | 2.8 | 4.6 | 2.5[b] |
| Average+ | 18 | 1.9 | 1.5 |
| No. of Readings | 1809 | 3993 | 2908 |

+Time period of average varies by site

*3-hour average from 6 to 9 a.m.

[a]Note federal ambient standard is for non-methane hydrocarbons (see Table 3)

[b]3-hour maximum taken on same day and hours as total hydrocarbons for comparison with standard. Value presented may not be actual maximum methane concentration.

TABLE 17

BUTTE/ANACONDA AREA NITROGEN DIOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Lincoln School (July 78 - Jul 79) | Hebgen Park (Apr 78-Feb 79, Sep 79-Jun 80) |
|---|---|---|
| 1-hour maximum | 0.05 | 0.20 |
| Average* | 0.007 | 0.024 |
| No. or Readings | 5255 | 6852 |

*Time period of average varies by site

At the Hebgen Park sampling site, ozone data were collected for slightly more than two years during MAPS. The maximum one-hour concentration was 0.117 ppm, while the second highest one-hour concentration was 0.099 ppm. This latter value falls below the Montana standard of 0.10 ppm and well below the federal standard of 0.12 ppm. The average concentration for the two years was 0.021 ppm.

Tables 19 and 20 also list the monthly average ozone concentrations at the Lincoln School and Hebgen Park sites, along with various other pollutants. The Lincoln School data indicates highest monthly average concentrations during the summer (May-July 1979). The lowest average concentrations occurred during the autumn and winter. The Hebgen Park data in Table 20 indicate a similar trend as that at Lincoln School, except that the highest average concentrations at Hebgen Park occurred in late spring and early summer.

Table 15 summarizes the carbon monoxide data for the Alpine West site and the Hebgen Park site in Butte. The Alpine West sampler was operated from January 1978 through August 1979. The maximum one-hour concentration of carbon monoxide at Alpine West was 16.0 ppm, which compares to the federal ambient standard of 35 ppm (not to be exceeded more than once per year) and the Montana ambient standard of 23 ppm (not to be exceeded more than once per year). The maximum eight-hour average carbon monoxide concentration at the Alpine West site was 8.4 ppm, which also was below the federal and Montana ambient standard of 9.0 ppm (not to be exceeded more than once per year). The average carbon monoxide concentration for twenty months was 1.0 ppm.

The Hebgen Park sampler was operated intermittantly from July 1978 to November 1979. Only portions of the seventeen-month period were available for summary due to operational problems with the sampling device. The maximum one-hour carbon monoxide concentration at the Hebgen Park site was 15.5 ppm, while the maximum eight-hour concentration was 7.8 ppm. Both concentrations were below the Montana and federal ambient standards. The average concentration over the sampling period was 0.9 ppm.

TABLE 18

BUTTE/ANACONDA AREA SULFUR DIOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Lincoln School (Mar 78-Jun 80) | C-Hill (Jan 78-Oct 78) | Post Office (Jan 78-Mar 78) | Mill Creek (Jan 78-Aug 79) | Hiway Jct. (Jan 78-Aug 79) | Hebgen Park (Jan 79-May 79) |
|---|---|---|---|---|---|---|
| 1-hour maximum (high) | 4.21 | 2.43 | 0.95 | 2.00 | 2.75 | 0.092 |
| 1-hour maximum (2nd high) | 1.80 | 2.40 | 0.67 | 1.62 | 2.30 | 0.090 |
| 3-hour maximum (high) | 2.25 | 1.75 | 0.60 | 1.50 | 2.09 | 0.073 |
| 3-hour maximum (2nd high) | 1.31 | 1.61 | 0.44 | 1.36 | 1.94 | 0.066 |
| 24-hour maximum (high)+ | 0.44 | 0.31 | 0.11 | 0.55 | 0.90 | 0.025 |
| 24-hour maximum (2nd high)+ | 0.38 | 0.27 | 0.11 | 0.45 | 0.79 | 0.024 |
| Average* | 0.030 | 0.038 | 0.020 | 0.033 | 0.052 | 0.009 |
| No. of readings | 8091 | 2375 | 1946 | 11,909 | 12,368 | 2385 |

*Time period of average varies by site
+Midnight to midnight

TABLE 19

LINCOLN SCHOOL MONTHLY AVERAGE AIR QUALITY SUMMARY

| Month | Total Susp. Particulates* | Suspended Part. 2.5 microns | Suspended Part. 2.5 to 15 microns | Sulfur* Dioxide | Nitrogen* Dioxide | Ozone* | Total Hydrocarbons |
|---|---|---|---|---|---|---|---|
| Mar 78 | --- | --- | --- | 0.01 | --- | --- | --- |
| Apr | --- | --- | --- | 0.04 | --- | --- | --- |
| May | 25 | --- | --- | 0.00 | --- | --- | --- |
| Jun | 45 | --- | --- | 0.00 | --- | --- | --- |
| Jul | 41 | --- | --- | 0.03 | 0.004 | --- | --- |
| Aug | 41 | 12 | 13 | --- | 0.003 | --- | --- |
| Sep | 39 | 13 | 13 | --- | --- | --- | --- |
| Oct | 55 | 11 | 29 | 0.03 | 0.004 | --- | --- |
| Nov | 46 | 20 | 17 | 0.03 | 0.011 | --- | --- |
| Dec | 22 | 17 | 8 | 0.02 | --- | 0.028 | --- |
| Jan 79 | 39 | 30 | 10 | 0.03 | 0.017 | 0.023 | 1.5 |
| Feb | 23 | 19 | 6 | 0.05 | 0.009 | 0.034 | --- |
| Mar | 90 | 12 | 36 | 0.03 | 0.005 | 0.036 | --- |
| Apr | 40 | 36 | 13 | 0.00 | 0.004 | 0.037 | --- |
| May | 55 | 8 | 30 | 0.02 | 0.004 | 0.038 | --- |
| Jun | 47 | 7 | 28 | 0.01 | 0.003 | 0.035 | 1.7 |
| Jul | 54 | 11 | 28 | 0.01 | 0.003 | 0.038 | 1.5 |
| Aug | 51 | 13 | 19 | 0.03 | 0.003 | 0.032 | --- |
| Sep | 90 | 14 | 30 | 0.07 | --- | 0.029 | 1.9 |
| Oct | 74 | 14 | 22 | 0.04 | --- | 0.023 | 1.9 |
| Nov | 89 | 26 | 27 | 0.04 | --- | 0.026 | 2.0 |
| Dec | 53 | 10 | 28 | 0.01 | --- | 0.028 | --- |
| Jan 80 | 49 | 23 | 11 | 0.04 | --- | 0.023 | --- |
| Feb | 76 | 19 | 22 | 0.04 | --- | 0.028 | --- |
| Mar | 60 | 9 | 30 | 0.02 | --- | 0.029 | --- |
| Apr | 88 | 11 | 26 | 0.05 | --- | 0.015 | --- |
| May | 42 | 9 | 12 | 0.08 | --- | --- | --- |
| Jun | 53 | 7 | 16 | 0.05 | --- | --- | --- |

*Values in parts per million
+Values in micrograms per cubic meter

TABLE 20

HEBGEN PARK MONTHLY AVERAGE AIR QUALITY SUMMARY

| Month | Total Susp.+ Particulates | Suspended Part. 2.5 microns | Suspended Part. 2.5 to 15 microns | Sulfur* Dioxide | Nitrogen* Dioxide | Ozone | Total* Hydrocarbons | Methane* Hydrocarbons | Carbon Monoxide |
|---|---|---|---|---|---|---|---|---|---|
| Mar 78 | --- | --- | --- | --- | --- | --- | 2.0 | --- | --- |
| Apr | --- | --- | --- | --- | 0.006 | 0.024 | 1.7 | --- | --- |
| May | 40 | --- | --- | --- | 0.000 | 0.037 | 1.7 | --- | --- |
| Jun | 56 | --- | --- | --- | 0.010 | 0.034 | 1.7 | --- | --- |
| Jul | 53 | --- | --- | 0.006 | 0.013 | 0.030 | 1.7 | 1.5 | 0.2 |
| Aug | 58 | --- | --- | 0.007 | --- | 0.029 | 1.7 | 1.5 | 0.2 |
| Sep | 59 | --- | --- | --- | 0.014 | 0.019 | --- | 1.4 | --- |
| Oct | 92 | --- | --- | --- | --- | 0.017 | 2.0 | 1.5 | 1.0 |
| Nov | 83 | 24 | 22 | --- | --- | 0.012 | 2.3 | 1.6 | 1.7 |
| Dec | 69 | 36 | 14 | --- | 0.035 | 0.010 | --- | --- | --- |
| Jan 79 | 92 | --- | --- | 0.010 | 0.063 | 0 005 | --- | --- | --- |
| Feb | 59 | 29 | 20 | 0.011 | 0.039 | 0.017 | --- | --- | --- |
| Mar | 102 | 20 | 36 | 0.011 | --- | 0.023 | --- | --- | --- |
| Apr | 58 | 12 | 36 | 0.007 | --- | 0.034 | --- | --- | --- |
| May | 75 | 12 | 37 | 0.007 | --- | 0.033 | --- | --- | --- |
| Jun | 84 | 11 | 36 | --- | --- | 0.031 | --- | --- | --- |
| Jul | 89 | 16 | 45 | --- | --- | 0.029 | --- | --- | 0.8 |
| Aug | 72 | 12 | 26 | --- | --- | 0.029 | --- | --- | 1.3 |
| Sep | 101 | 17 | 34 | --- | 0.018 | 0.016 | --- | --- | 0.9 |
| Oct | 88 | 23 | 36 | --- | 0.008 | 0.013 | --- | --- | 0.9 |
| Nov | 128 | 32 | 32 | --- | 0.016 | 0.007 | --- | --- | 0.9 |
| Dec | 128 | 26 | 31 | --- | 0.019 | 0.010 | --- | --- | --- |
| Jan 80 | 110 | 38 | 37 | --- | 0.026 | 0.008 | --- | --- | --- |
| Feb | 101 | 26 | 26 | --- | 0.029 | 0.011 | --- | --- | --- |
| Mar | 80 | 21 | 25 | --- | 0.016 | 0.023 | --- | --- | --- |
| Apr | 109 | 21 | 45 | --- | 0.015 | 0.030 | --- | --- | --- |
| May | 66 | 18 | 14 | --- | 0.013 | 0.039 | --- | --- | --- |
| Jun | 46 | 13 | 16 | --- | 0.012 | 0.013 | --- | --- | --- |

*Values in parts per million
+Values in micrograms per cubic meter

Table 20 lists the monthly average carbon monoxide concentrations at the Hebgen Park site. Because of a short and interrupted sampling period, no seasonal trend is evident.

Table 16 summarizes the total hydrocarbon data for the Lincoln School site and the total and methane hydrocarbon data for the Hebgen Park site. The Lincoln School site was operated in January and from June through November 1979. The maximum three-hour concentration for the hours of 0600 to 0900 was 3.2 ppm. The federal ambient standard, although not currently enforced, is 0.24 ppm for non-methane hydrocarbons only. Therefore, a direct comparison with the standard is not possible using these data. The average concentration over the entire sampling period was 1.8 ppm.

The Hebgen Park sampler was operated from March through November 1978 for total hydrocarbons and from July through November 1978 for methane hydrocarbons. The maximum three-hour concentration of total hydrocarbons for the 0600 to 0900 time period was 4.8 ppm, with a corresponding concentration of 1.9 ppm methane hydrocarbons at the same time. The second highest three-hour concentration was 4.6 ppm for total hydrocarbons with a corresponding value of 2.5 ppm for methane hydrocarbons. The difference between the total and methane hydrocarbons for the second highest three-hour period is 2.1 ppm.

Table 17 summarizes the nitrogen dioxide data from the Lincoln School and Hebgen Park sites. Data were collected from the Lincoln School site from July 1978 through July 1979. The maximum one-hour concentration at the Lincoln School site was 0.05 ppm, which compares with Montana's ambient standard of 0.30 ppm, not to be exceeded more than once per year. The average concentration over the one year of data collection was 0.007 ppm. The federal and Montana annual standard is 0.05 ppm.

The Hebgen Park sampler was operated intermittantly from April 1978 through June 1980. The maximum one-hour concentration was 0.20 ppm, while the average concentration over the entire sampling period was 0.024 ppm.

Tables 19 and 20 list the monthly average nitrogen dioxide concentrations for the Lincoln School and Hebgen Park sites, respectively. At the Lincoln School site, the monthly averages indicate highest levels in winter with lowest levels in mid-summer. Hebgen Park data show a similar trend to those from Lincoln School.

Table 18 summarizes the sulfur dioxide data collected from six stations in the Butte/Anaconda area during MAPS. The Lincoln School station was operated from March 1978 through June 1980. The maximum and second-highest one-hour concentrations at the Lincoln School were 4.21 and 1.80 ppm, respectively, as compared to the Montana ambient one-hour standard of 0.50 ppm, not to be exceeded more than eighteen times in twelve consecutive months. The three-hour maximum sulfur dioxide concentration at the Lincoln School was 2.25 ppm, while the second highest three-hour concentration during the same year was 1.31 ppm. This compares with the federal secondary standard of 0.50 ppm not to be exceeded more than once per year. The maximum twenty-four hour and second highest twenty-four hour concentrations at the Lincoln School were 0.44 and 0.38 ppm, respectively. These values also exceed the federal primary standard of 0.14 ppm and the Montana standard of 0.10 ppm, not to be exceeded more than once per year. The average concentration at the Lincoln School site over the sampling period was 0.030 ppm. This compares with the federal annual standard of 0.03 ppm and the Montana standard of 0.02 ppm.

The C-Hill sampler was operated south of Anaconda from January through October 1978 during MAPS. The maximum and second highest one-hour concentrations

of sulfur dioxide were 2.43 and 2.40 ppm, respectively. The maximum and second highest three-hour concentrations at C-Hill were 1.75 and 1.61 ppm, respectively. Similarly the twenty-four hour maximum concentrations were 0.31 and 0.27 ppm, respectively. The overall average concentration during the sampling period was 0.038 ppm. Both the federal and Montana ambient standards for various time periods were exceeded at the C-Hill station.

The Post Office Station, which operated from January through March 1978, had second highest one-hour, three-hour, and twenty-four hour concentrations of 0.67, 0.44, and 0.11 ppm, respectively. Similarly the second highest concentrations at Mill Creek, which operated from January 1978 through August 1979, were 1.62, 1.36 and 0.45 ppm, respectively.

At the Highway Junction site, the sampler was operated during MAPS from January 1978 through August 1979. Maximum one-hour and second-highest one-hour sulfur dioxide concentrations were 2.75 and 2.30 ppm, respectively. Highest and second-highest three-hour sulfur dioxide concentrations were 2.09 and 1.94 ppm, respectively. Similarly, the highest and second highest twenty-four concentrations were 0.90 and 0.79 ppm, respectively. The overall average concentration at the Highway Junction site during the sampling period was 0.052 ppm.

The Hebgen Park sampler was operated for a short period during 1979 for measuring sulfur dioxide; only five months' data were available due to instrument malfunctions. The maximum one-hour, three-hour, and twenty-four hour sulfur dioxide concentrations were 0.092, 0.073, and 0.025 ppm. The overall average concentration for the sampling period was 0.009 ppm.

In Table 19, the monthly average sulfur dioxide concentrations at Lincoln School are listed. Seasonal trends are not readily evident from the data listed. Overall trends, however, show a general increase in sulfur dioxide concentrations from 1978 to 1980.

## C. SUMMARY AND CONCLUSIONS

MAPS has provided valuable data on air pollution levels found in the Anaconda-Butte area. Data were collected on concentrations of total suspended particulates, fine particulates, trace elements, and gaseous pollutants. Total suspended particulate data indicates concentrations in excess of the federal primary and secondary and Montana twenty-four hour standards. The federal primary and secondary and Montana annual particulate standards also were exceeded. The highest particulate levels were recorded in Butte. Highest monthly average particulate concentrations generally occurred during the autumn, whereas lowest concentrations occurred during the winter.

Although no federal or Montana standard has been adopted, inhalable particulate data revealed interesting trends and provided valuable data for the health effects studies. Generally, the fine particulates' fine fraction had highest concentrations in the late autumn or winter and lowest concentrations in the late spring and summer. The fine fraction generally contributed 33 to 50 percent of the total fine particulates. The concentration of the fine fraction also followed very closely to that of the nephelometer scattering coefficient. The coarse fraction did not show as definite trends as the fine fraction. Generally the coarse fraction contributed 67 to 50 percent of the total fine particulates.

Trace element data generally revealed differences between the Anaconda and Butte areas. Trace element data revealed higher levels of aluminum, iron, manganese, and nitrate at Hebgen Park in Butte, with higher levels of arsenic, cadmium, copper, nickel, zinc, and sulfates at Lincoln School in Anaconda.

Ozone data colleted in the Anaconda-Butte area revealed levels below the federal and Montana standards for the second-highest readings. Highest readings

were recorded in Butte at Hebgen Park, but the overall average ozone concentration was higher at Lincoln School in Anaconda. Highest concentrations occurred during the autumn and winter, whereas lowest concentrations occurred during the late spring and early summer.

Carbon monoxide concentrations were measured only in Butte, and concentrations were below the federal and Montana standards. Similarly, hydrocarbon concentrations also were collected only in Butte. Measurements of both total and methane hydrocarbons provided a comparison that revealed non-methane hydrocarbons in excess of the federal guideline value. Nitrogen dioxide data in Anaconda and Butte revealed levels below both the federal and Montana standards.

Sulfur dioxide concentrations were recorded in both Anaconda and Butte with much higher levels recorded in Anaconda due to the copper smelter emissions. Levels in excess of the federal and Montana standards were recorded at one or more stations in the Anaconda area.

# III. BILLINGS

This chapter summarizes the ambient air quality data collected in the city of Billings and some of the surrounding areas. Data on total suspended particulates, sulfur dioxide, nitrogen dioxide, total hydrocarbons, carbon monoxide, ozone, and fine particulates are discussed.

The Billings area's elevation varies from about 3100 feet to 3600 feet above sea level. The area is located between the Great Plains and the Rocky Mountains, and therefore, has a climate characteristic of both regions. The Yellowstone River Valley, which includes a major portion of the city of Billings, has a major influence on the city's climate, as it influences the local wind patterns, which are important in determining where and how quickly air pollutants are transported.

Billings and Laurel, located fifteen miles southwest of Billings, contain significant industries. Three refineries, a coal-fired power plant, a sugar beet factory, and a sulfur plant are all important business activities in the area, as well as significant sources of air pollution. These sources, along with automobile emissons and home heating emissions, contribute to air pollution levels observed in the area.

## A. METHODOLOGY

Prior to MAPS, the Air Quality Bureau and the Yellowstone County Air Pollution Control Agency operated several ambient air monitoring stations in

and around Billings. With the advent of MAPS, the number of stations and monitored air pollutants were increased. Primary emphasis of the MAPS air quality monitoring was to monitor the areas of greatest population exposure, i.e. central Billings. Table 21 lists the various sampling sites operated during MAPS in the Billings area, the parameters sampled, the analysis method used in obtaining the data, and the area type. Figure 17 illustrates the sites' locations.

The Central Park site is located in central Billings in a residential area, while the Lockwood School site is located in eastern Billings, just south of the interstate highway in a mixed residential and industrial setting. The Twenty-seventh Street and Montana Avenue site is in downtown Billings, a commercial area composed of primarily office buildings, retail stores, and shops. The City Hall site also is located downtown Billings in a commercial area of office buildings and shops. The Grand Avenue School is located in west-central Billings in a mixed residential and commercial setting, which includes some offices and shops. The Farm East of Cenex site, as the name implies, is located southeast of the Farmers Union Central Exchange (Cenex) oil refinery south of Laurel. Therefore, the setting is industrial and rural-agricultural. The KGHL site southwest of Billings is situated in a commercial-agricultural area, the Bench School site is located in the Billings Heights area (northeast Billings), and the the Fairgrounds site is found in east-central Billings in a commercial area.

The data are presented in this chapter by pollutant. Comparisons are made with the Montana Ambient Air Quality Standards (MAAQS) and the National Ambient Air Quality Standards (NAAQS), which are listed in Tables 2 and 3, respectively. The national or federal standards include both the primary and secondary standards.

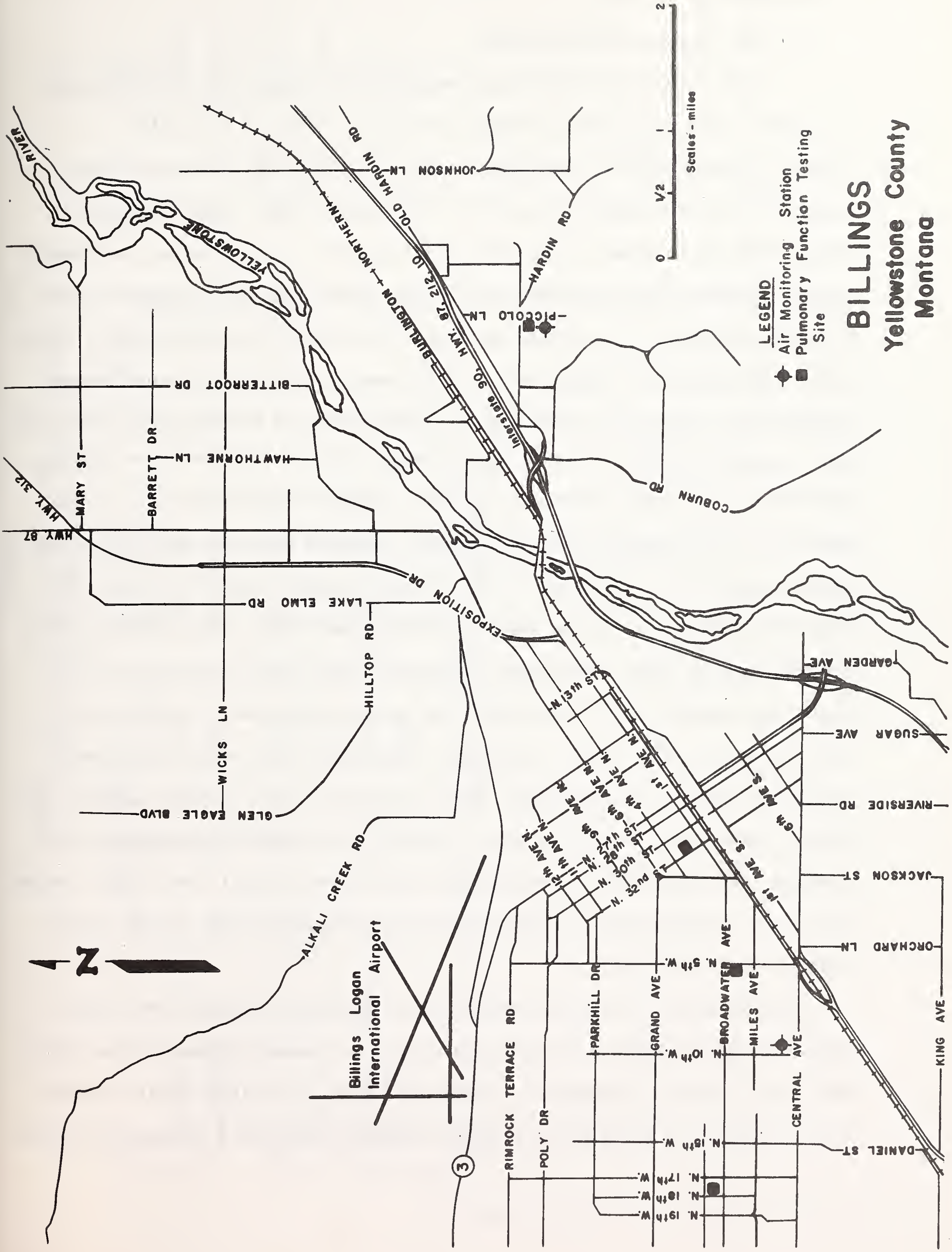
TABLE 21

BILLINGS AREA SAMPLING SITES AND PAPAMETERS

| Site | Location (Area type) | Parameters Sampled | Analysis Method |
|---|---|---|---|
| Central Park | Central Billings (residential) | Total Suspended Particulate | Gravimetric-High-Volume Air Sampler |
| | | Fine Suspended Particulates | Gravimetric-Dichotomous Air Sampler |
| | | Nitrogen Dioxide | Chemiluminescence |
| | | Oxides of Nitrogen | Chemiluminescence |
| | | Nitric Oxide | Chemiluminescence |
| | | Ozone | Chemiluminescence |
| | | Total Hydrocarbons | Flame Ionization |
| | | Sulfur Dioxide | Pulsed Fluorescent |
| | | Trace Elements | Atomic Absorption - High-Volume air Samples |
| | | Trace Elements | Atomic Absorption - Membrane Sampler |
| Lockwood School | East Billings (Residential - Industrial) | Total Suspended Particulates | Gravimetric - High-Volume Air Sampler |
| | | Sulfur Dioxide | Pulsed Fluorescent |
| | | Fine Suspended Particulate | Gravimetric - Dichotomous Air Sampler |
| | | Nitrogen Dioxide | Chemiluminescence |
| | | Trace Elements | Atomic Absorption - High-Volume Air |
| Samples | | | |
| 27th and Montana | East Central Billings (Commercial) | Nitrogen Dioxide | Chemiluminescence |
| | | Total Hydrocarbons | Flame Ionization |
| | | Carbon Monoxide | Nondispersive Infra-red |
| | | Ozone | Chemiluminescence |
| | | Sulfur Dioxide | Coulometric |
| | | Trace Elements | Atomic Absorption - Membrance Sampler |
| City Hall | East Central Billings (Commercial) | Total Suspended Particulates | Gravimetric-High-Volume Air Sampler |
| | | Trace Elements | Atomic Absorption - High Volume Air Samples |

| | | | |
|---|---|---|---|
| Grand Ave. School | West Central Billings (residential - commercial) | Total Suspended Particulates<br>Trace Elements | Gravimetric-High-Volume Air Sampler<br>Atomic Absorption - High-Volume Air Samples |
| Farm East of Cenex | Southeast of Laurel (rural-industrial) | Sulfur Dioxide<br>Sulfur Dioxide<br>Sulfur Dioxide | Pararosaniline sulfanic<br>Coulometric<br>Pulsed Fluorescent |
| KGHL | Southwest of Billings (commercial) | Total Suspended Particulate | Gravimetric - High-Volume Air Sampler |
| Bench School | Northeast Billings (residential) | Total Suspended Particulates | Gravimetric-High-Volume Air Sampler |
| Fairgrounds | East Central Billings (commercial) | Ozone<br>Carbon Monoxide | Chemiluminescence<br>Nondispersive Infra-red |

Figure 17


BILLINGS
Yellowstone County
Montana
LEGEND
Air Monitoring Station
Pulmonary Function Testing Site
Scale - miles
0
1/2
1
2
YELLOWSTONE RIVER
JOHNSON LN
OLD HARDIN RD
BURLINGTON NORTHERN
HWY. 87, 212, 10
Interstate 90
HARDIN RD
PICCOLO LN
COBURN RD
BITTERROOT DR
HAWTHORNE LN
MARY ST
BARRETT DR
HWY 312
HWY 87
EXPOSITION DR
LAKE ELMO RD
HILLTOP RD
WICKS LN
GLEN EAGLE BLVD
ALKALI CREEK RD
Billings Logan International Airport
3
GARDEN AVE
SUGAR AVE
RIVERSIDE RD
JACKSON ST
ORCHARD LN
KING AVE
DANIEL ST
N. 13th ST
1st AVE N.
4th AVE N.
6th AVE N.
9th AVE N.
11th AVE N.
12th AVE N.
N. 27th ST
N. 28th ST
N. 30th ST
N. 32nd ST
1st AVE S.
5th AVE S.
6th AVE S.
RIMROCK TERRACE RD
POLY DR
PARKHILL DR
GRAND AVE
BROADWATER AVE
MILES AVE
CENTRAL AVE
N. 5th W.
N. 10th W.
N. 15th W.
N. 17th W.
N. 18th W.
N. 19th W.
N

## B. PRESENTATION OF RESULTS

### 1. Total Suspended Particulates

Total suspended particulate concentrations as measured by high-volume air samplers are summarized in Tables 22 and 23. Table 22 lists the highest-, second-highest, and third-highest concentrations of particulates measured during the cited time period. The second-highest and third-highest concentrations are shown in addition to the highest, as the Montana and federal ambient standards allow one excursion of the twenty-four hour standard without a violation occurring. The second excursion at the same site constitutes a violation of the standard. Among the six sites shown in Table 22, concentrations exceeding the twenty-four hour federal primary value of 250 micrograms per cubic meter (ug/m$^3$) occurred at the Lockwood School, City Hall, Grand Avenue School, and Central Park sites. However, only the Lockwood School site had a second excursion of the federal primary standard. A second excursion does not automatically constitute a violation of the standard as both excursions must occur within the same year. In the case of the Lockwood School site, both excursions did occur during 1978. The federal secondary twenty-four hour value of 150 ug/m$^3$ was exceeded at all six sites, and second excursions occurred at all sites except the KGHL site. The highest twenty-four hour particulate concentration measured was 353 ug/m$^3$, which occurred at the Lockwood School. The Montana twenty-four hour particulate standard of 200 ug/m$^3$ was exceeded at the Lockwood School, City Hall, Grand Avenue School, and Central Park sites. Second excursions of the Montana standard occurred at Lockwood School, Grand Avenue School, and Central Park.

Table 22 also lists the arithmetic mean, arithmetic standard deviation, geometric mean, geometric standard deviation, and number of observations taken. Both the arithmetic and geometric means are listed in Table 22 as the Montana annual standard is based on an arithmetic mean of any twelve consecutive months,

TABLE 22

BILLINGS AREA TOTAL SUSPENDED PARTICULATE SUMMARY
(Values in micrograms per cubic meter)

| Site | Maximum Readings High | 2nd High | 3rd High | Arithmetic Mean | Std.Dev. | Geometric Mean | Std.Dev. | No. of Observ. | Time Period |
|---|---|---|---|---|---|---|---|---|---|
| Bench School | 180 | 162 | 155 | 63 | 36 | 54 | 1.7 | 76 | 2/79-6/80 |
| Lockwood School | 353 | 258 | 225 | 61 | 50 | 48 | 1.8 | 110 | 1/78-7/78<br>5/79-5/80 |
| KGHL | 155 | 130 | 128 | 46 | 25 | 39 | 1.8 | 148 | 1/78-6/80 |
| City Hall | 288 | 175 | 166 | 76 | 40 | 66 | 1.7 | 146 | 1/78-6/80 |
| Grand Avenue School | 302 | 214 | 187 | 69 | 46 | 53 | 2.1 | 137 | 1/78-6/80 |
| Central Park | 266 | 246 | 238 | 87 | 47 | 66 | 1.9 | 530* | 6/78-5/80 |

*Sampling frequency greater than standard every sixth day schedule

TABLE 23

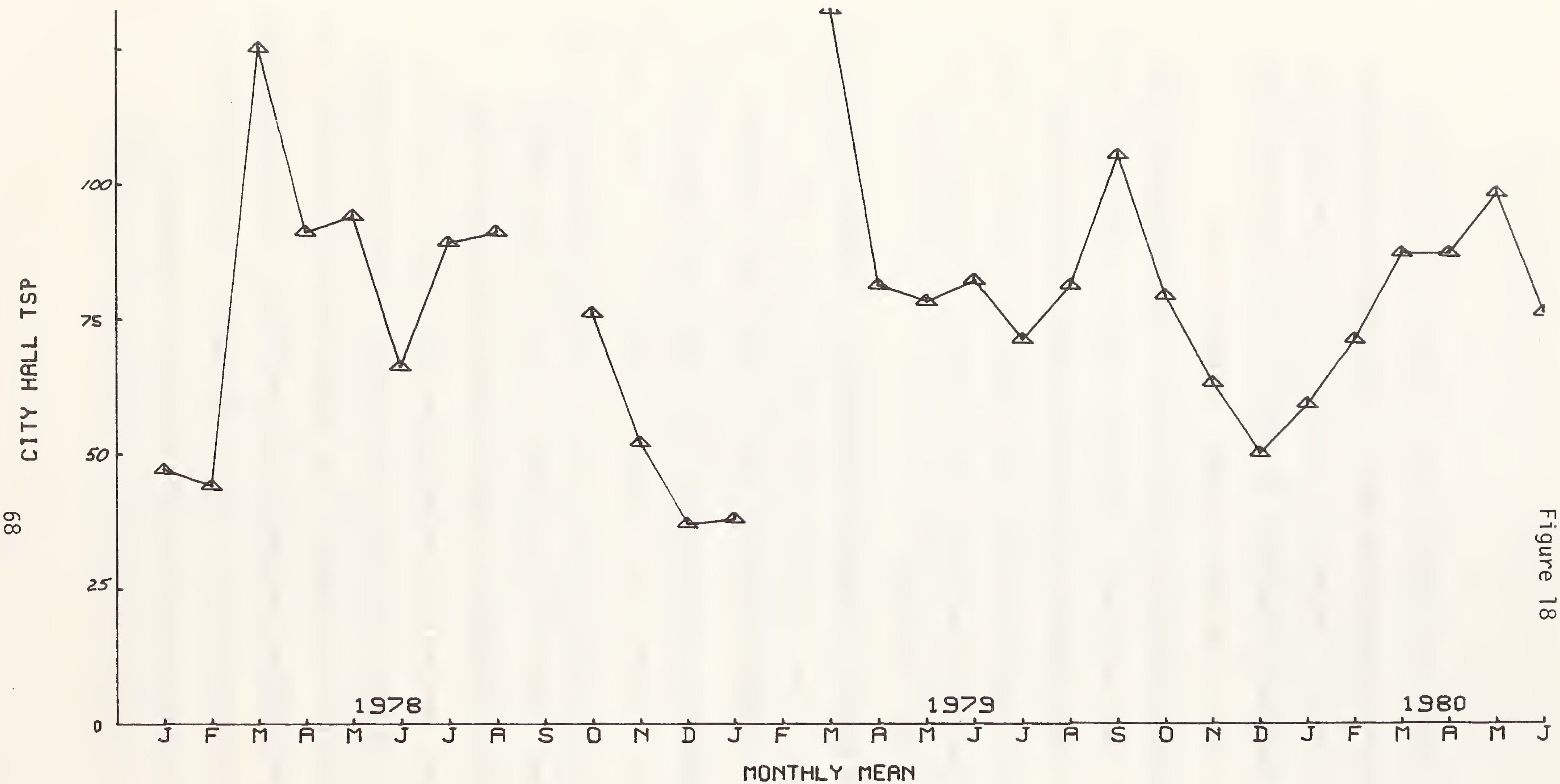
BILLINGS AREA MONTHLY AVERAGE PARTICULATE LEVELS
(Values in micrograms per cubic meter)

| Month | Bench School Max. | Bench School Ave. | Lockwood School Max. | Lockwood School Ave. | KGHL Max. | KGHL Ave. | City Hall Max. | City Hall Ave. | Grand Ave. School Max. | Grand Ave. School Ave. | Central Park Max. | Central Park Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. 78 | --- | --- | 79 | 51 | 74 | 25 | 77 | 47 | 19 | 12 | --- | --- |
| Feb. | --- | --- | 58 | 40 | 87 | 45 | 74 | 44 | 27 | 14 | --- | --- |
| Mar | --- | --- | 135 | 66 | 50 | 35 | 175 | 125 | 171 | 118 | --- | --- |
| Apr | --- | --- | 122 | 75 | 60 | 48 | 103 | 91 | 110 | 83 | --- | --- |
| May | --- | --- | 63 | 48 | 39 | 29 | 122 | 94 | 146 | 93 | --- | --- |
| Jun | --- | --- | 94 | 45 | 45 | 35 | 87 | 66 | 76 | 61 | 143 | 79 |
| Jul | --- | --- | 81 | 49 | 69 | 49 | 110 | 89 | 96 | 72 | 183 | 82 |
| Aug | --- | --- | --- | --- | 84 | 65 | 116 | 91 | 89 | 67 | 196 | 109 |
| Sep | --- | --- | --- | --- | 92 | 48 | 138 | 73 | 100 | 60 | 159 | 82 |
| Oct | --- | --- | --- | --- | 78 | 51 | 118 | 76 | 77 | 49 | 124 | 85 |
| Nov | --- | --- | --- | --- | 155 | 74 | 126 | 52 | 20 | 10 | 136 | 66 |
| Dec | --- | --- | --- | --- | 47 | 32 | 68 | 37 | 23 | 18 | 49 | 29 |
| Jan. 79 | --- | --- | --- | --- | 50 | 36 | 69 | 38 | 50 | 30 | 54 | 34 |
| Feb | 65 | 42 | --- | --- | 69 | 46 | 81 | 61 | 75 | 54 | 82 | 41 |
| Mar | 162 | 68 | --- | --- | 49 | 38 | 288 | 132 | 302 | 165 | 246 | 70 |
| Apr | 106 | 57 | --- | --- | 46 | 36 | 122 | 81 | 171 | 98 | 134 | 79 |
| May | 127 | 63 | 59 | 55 | 65 | 48 | 113 | 78 | 111 | 69 | 236 | 95 |
| Jun | 71 | 56 | 120 | 91 | 65 | 46 | 94 | 82 | 78 | 69 | 238 | 105 |
| Jul | --- | --- | 93 | 82 | 81 | 55 | 100 | 71 | 86 | 59 | 212 | 108 |
| Aug | 155 | 67 | 123 | 76 | 99 | 48 | 151 | 81 | 147 | 73 | 227 | 121 |
| Sep | 151 | 115 | 353 | 169 | 130 | 85 | 134 | 105 | 121 | 92 | 266 | 137 |
| Oct | 122 | 68 | 79 | 48 | 97 | 46 | 123 | 79 | 108 | 88 | 143 | 71 |
| Nov | 94 | 45 | 78 | 52 | 58 | 36 | 102 | 63 | 89 | 61 | 117 | 73 |
| Dec | 61 | 42 | 59 | 45 | 39 | 35 | 64 | 50 | 54 | 45 | 180 | 86 |
| Jan. 80 | --- | --- | 28 | 24 | 72 | 46 | 134 | 59 | 136 | 63 | 158 | 57 |
| Feb | 75 | 47 | 47 | 31 | 51 | 36 | 116 | 71 | 154 | 90 | 93 | 52 |
| Mar | 74 | 48 | 32 | 28 | 85 | 37 | 166 | 87 | 214 | 111 | 143 | 66 |
| Apr | 108 | 72 | 112 | 66 | 128 | 59 | 124 | 87 | 122 | 85 | 215 | 103 |
| May | 180 | 87 | 110 | 75 | 114 | 58 | 140 | 98 | 159 | 83 | 215 | 103 |
| Jun | 89 | 65 | --- | --- | 84 | 51 | 95 | 76 | 72 | 61 | --- | --- |

whereas the federal primary and secondary annual standards are based on a geometric mean of any twelve consecutive months. The federal primary annual standard of 75 ug/m$^3$ geometric average was not exceeded at any of the sites. However, the federal secondary standard of 60 ug/m$^3$ was exceeded at the City Hall and Central Park sites. The Montana annual standard of 75 ug/m$^3$ (arithmetic) also was exceeded at the City Hall and Central Park sites. The maximum arithmetic mean occurred at the Central Park site (87 ug/m$^3$), while the maximum geometric mean occurred at both the City Hall and Central Park sites (66 ug/m$^3$). All samplers except the high-volume sampler at Central Park were run on the standard schedule of one sample every six days. The Central Park sampler was operated almost every day.

Table 23 lists the monthly arithmetic average total suspended particulate concentrations measured at the six sites in the Billings area. (The maximum twenty-four hour concentrations of particulates for each month also are listed.) These same monthly averages are shown for the City Hall, Grand Avenue School, and Central Park sites in Figures 18, 19, and 20, respectively. In the figures, monthly averages were not plotted if less than four samples were available for averaging. At the Bench School site, the trend in Table 23 shows highest average concentrations in September and lowest concentrations in November through February. Since particulate concentrations vary directly with snow cover, precipitation, and wind, one year's data does not accurately describe a seasonal trend. This again is evident in the Lockwood School data, which show high concentrations in September and June during the 1979-80 collection, whereas the 1978 data show low concentrations in June. The maximum concentrations at the Bench School and Lockwood sites occurred in March and September, respectively.

Figure 18

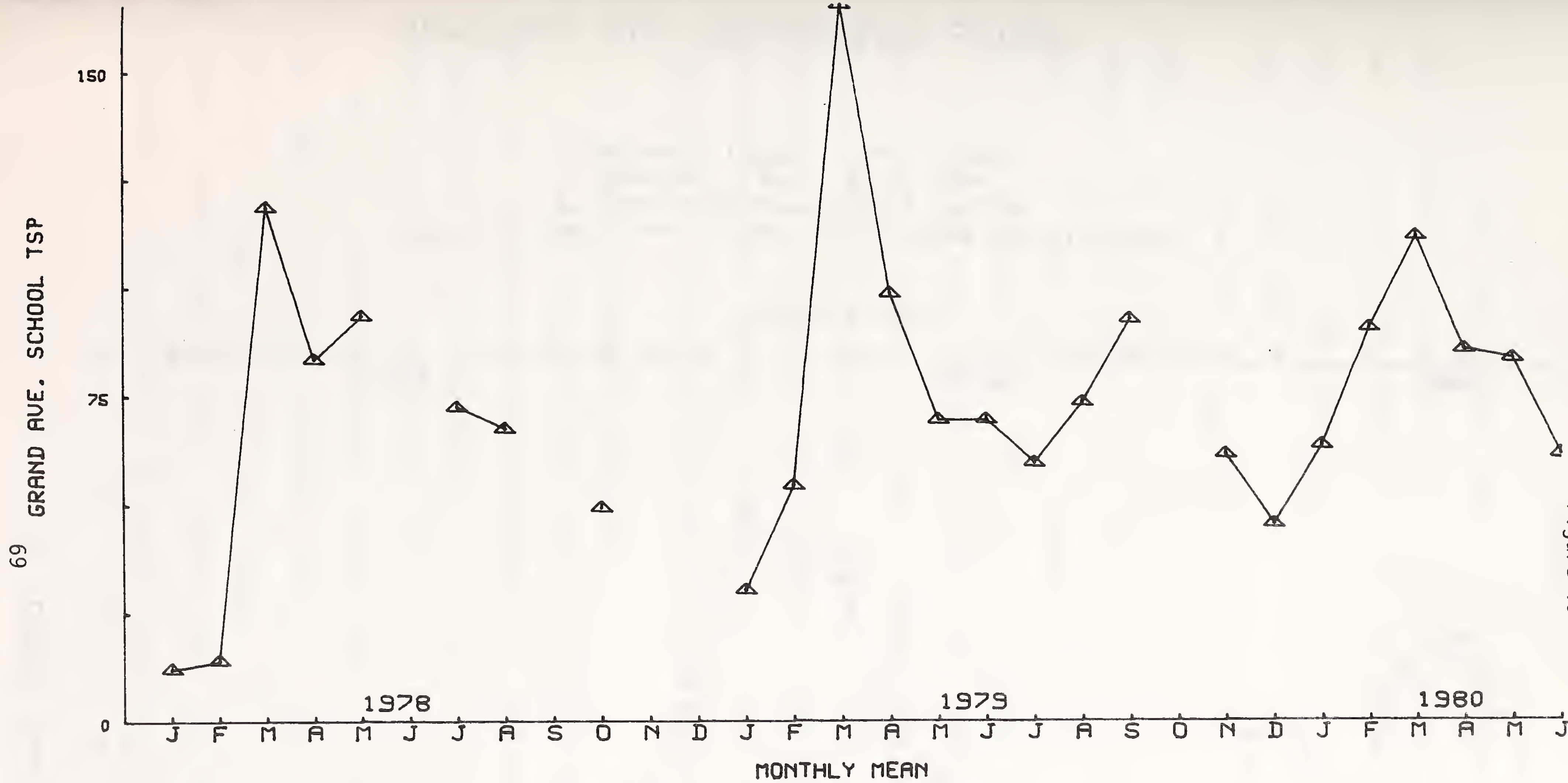



Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
City Hall Billings
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 19

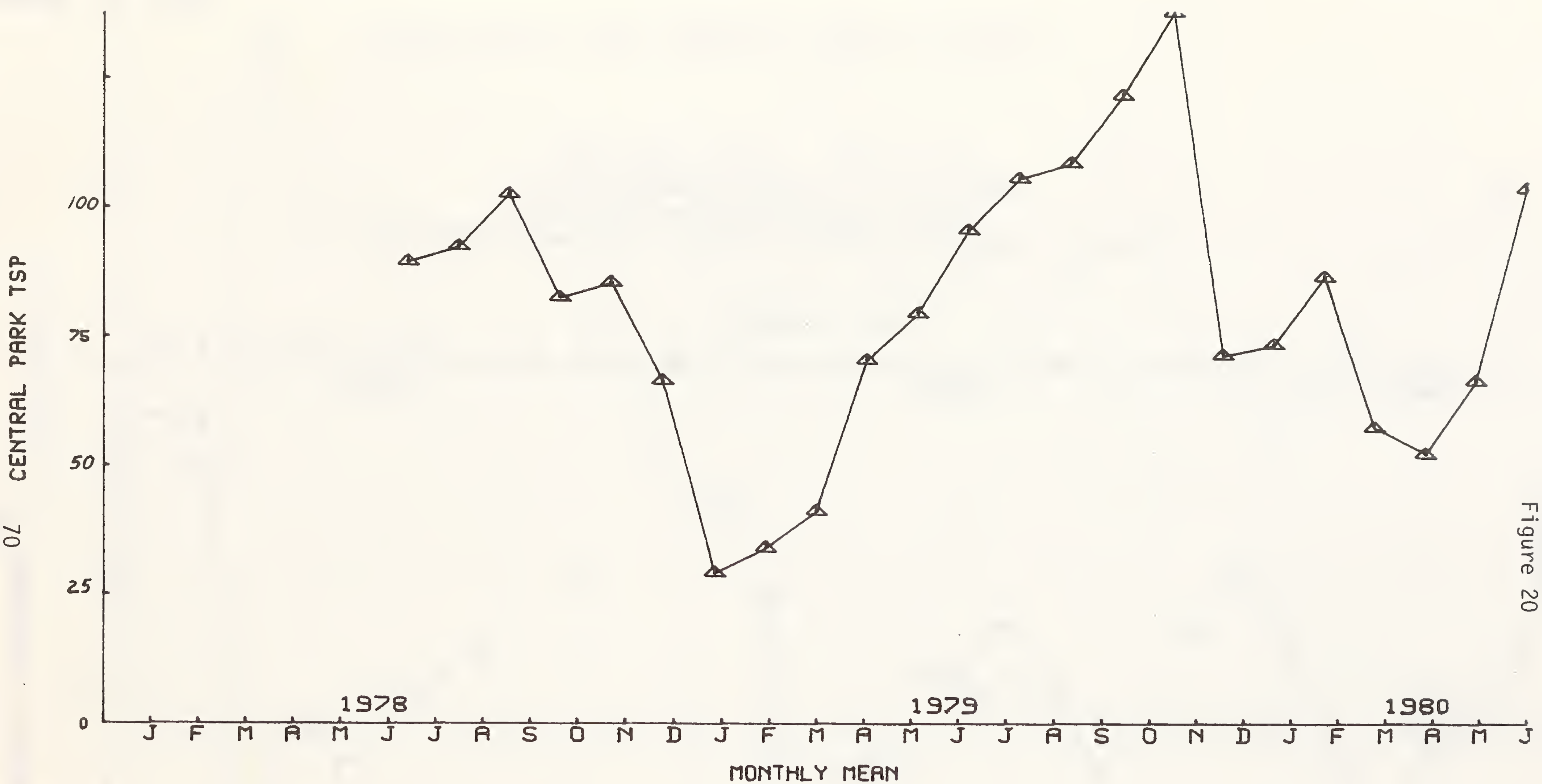



Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Grand Avenue School Billings
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 20




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Central Park Billings
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 18 and Table 23 show a more predominant trend at the City Hall site. Higher concentrations occur during the early spring (March) each year, whereas lower concentrations occur during the winter (December-January). The overall trend appears to be toward higher particulate concentrations throughout the year from 1978 through 1980.

Figure 19 and Table 23 also show a similar seasonal trend at the Grand Avenue School. Lower particulate concentrations occurred during the winter (December-February), whereas higher concentrations occurred during early spring (March). With the exception of a few months, the overall trend indicated higher particulate concentrations in 1980 than during previous years.

Table 24 and Figure 20 show the trend at the Central Park site. Although less data were available at the site, a trend somewhat different than that found at City Hall or Grand Avenue School is apparent in that higher concentrations of particulates occurred during the late summer or early autumn, whereas lower concentrations occurred during the winter and early spring. Again the trend was toward higher concentrations during 1979-80 versus 1978-79.

2. Inhalable Suspended Particulates

During the MAPS monitoring program, a network of samplers was established throughout the state to measure the concentration of inhalable suspended particulates. See Chapter II for a description of this network. Two samplers were located in Billings at Central Park and Lockwood School.

Table 24 summarizes the monthly average values at Central Park of the two size ranges, i.e. the total inhalable particulates and the total suspended particulates as measured by a high volume sampler. The particles less than 2.5 microns show the least variation. Average values vary from 10 ug/m$^3$ in May 1980 to 28 ug/m$^3$ in February, 1979. The average concentration of particles less than

2.5 microns is 17 ug/m$^3$. The monthly average concentration of particles in the 2.5 to 15 micron size range vary from 2 ug/m$^3$ in February 1979 to 58 ug/m$^3$ in September, 1979. The average concentration of particles from 2.5 to 15 microns is 27 ug/m$^3$. Therefore, on the average, the particles less than 2.5 microns constitute 39 percent of the fine particulate concentration at the Central Park site. These concentrations are by mass, i.e., micrograms per cubic meter, and not by number of particles. Since the particles less than 2.5 microns are smaller than particles from 2.5 to 15 microns, it takes more of the smaller particles to make the same weight as the larger particles. Figures 21 through 23 display the monthly average values of the two size ranges and their total concentration at the Central Park site. The data for the particles less than 2.5 microns do not show any clear seasonal trend, because variation in the concentration appears to be random from month to month. The coarse fraction plot (Figure 22) indicates a trend toward higher concentrations in the late autumn and early winter with lowest concentrations appearing during the spring and early summer. Figure 23 shows the inhalable particulate concentration by monthly average. Since the coarse fraction contributed to over 61 percent of the total inhalable mass, the trend presented in Figure 22 is similar to that in Figure 23. Higher concentrations of inhalable particulates occurred during the autumn and winter than during the remainder of the year.

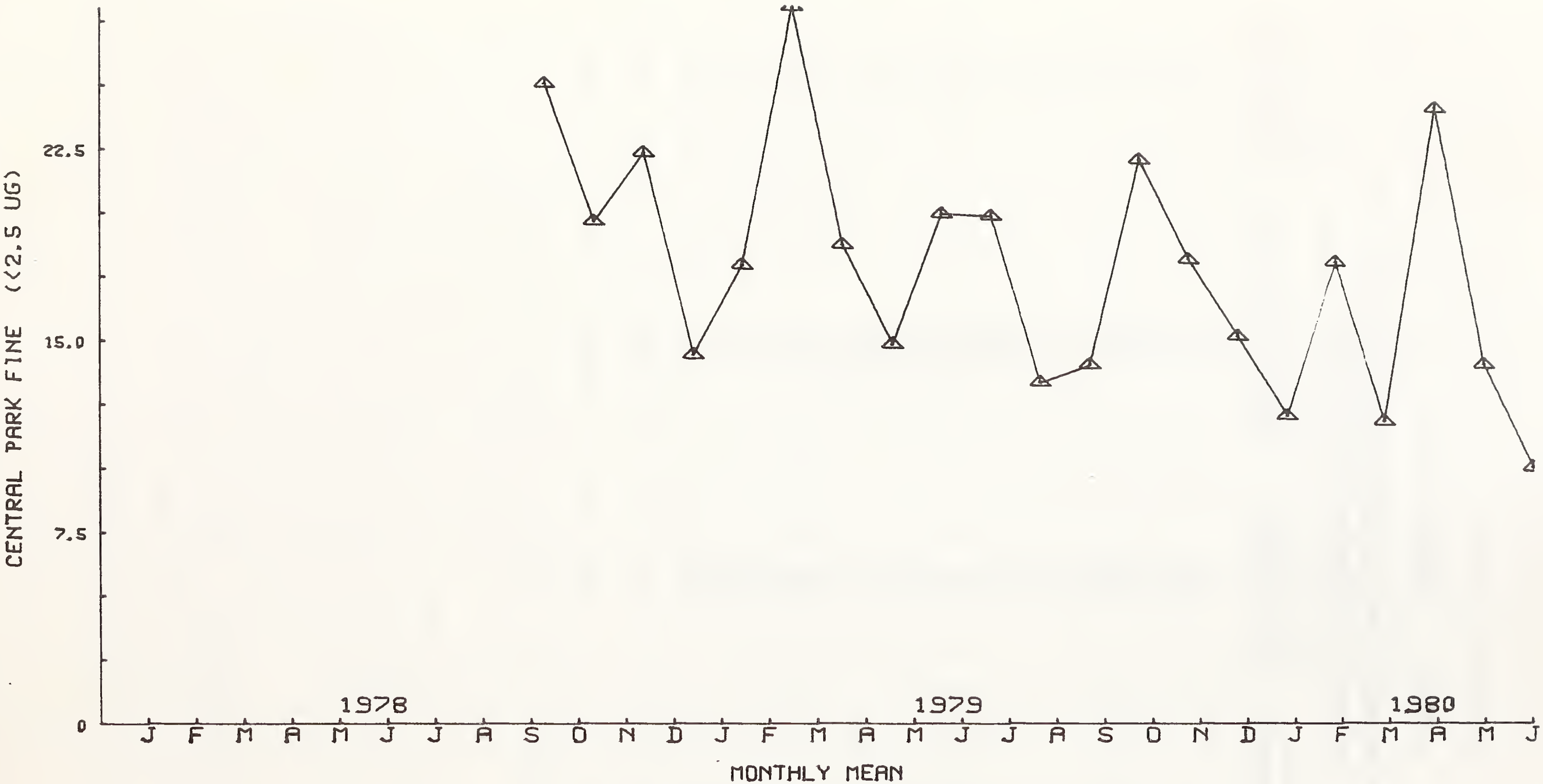
In Table 24 the comparison of the total suspended particulates with the concentrations of the various sizes of fine particulates at Central Park shows that on the average 23 percent of the total particulates were particles less than 2.5 microns. Similarly, 37 percent of the total particulate concentration was in the size range of 2.5 to 15 microns. The percentage of the fine particulate contribution to the total concentration varied from month to month.

TABLE 24

CENTRAL PARK MONTHLY AVERAGE PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Susp. Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Sep 78 | 82 | 25 | 13 | 37 |
| Oct | 85 | 20 | 14 | 33 |
| Nov | 66 | 22 | 21 | 43 |
| Dec | 29 | 14 | 14 | 28 |
| Jan 79 | 34 | 18 | 4 | 21 |
| Feb | 41 | 28 | 2 | 30 |
| Mar | 70 | 19 | 13 | 32 |
| Apr | 79 | 15 | 9 | 24 |
| May | 95 | 20 | 20 | 39 |
| Jun | 105 | 20 | 36 | 56 |
| Jul | 108 | 13 | 43 | 56 |
| Aug | 121 | 14 | 37 | 51 |
| Sep | 137 | 22 | 58 | 80 |
| Oct | 71 | 18 | 34 | 52 |
| Nov | 73 | 15 | 32 | 47 |
| Dec | 86 | 12 | 42 | 54 |
| Jan 80 | 57 | 18 | 17 | 34 |
| Feb | 52 | 12 | 12 | 26 |
| Mar | 66 | 24 | 34 | 58 |
| Apr | 103 | 14 | 39 | 53 |
| May | 109 | 10 | 33 | 43 |
| Average | 73 | 17 | 27 | 44 |
| Average (Jul 79-Apr 80) | 90 | 16 | 34 | 50 |

Figure 21

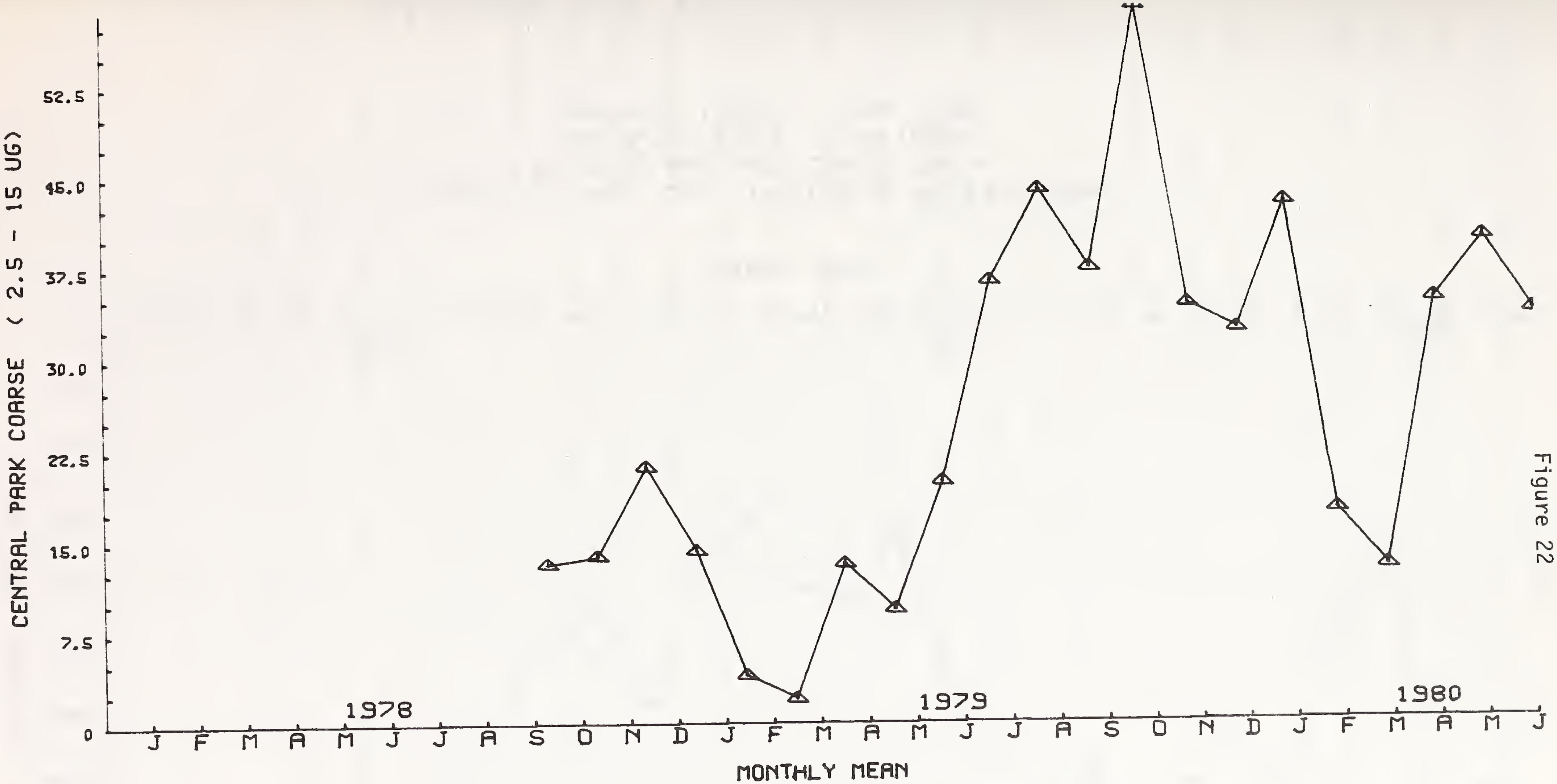



Monthly Mean vs. Fine Particulate
Micrograms per Cubic Meter
Central Park Billings
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 22

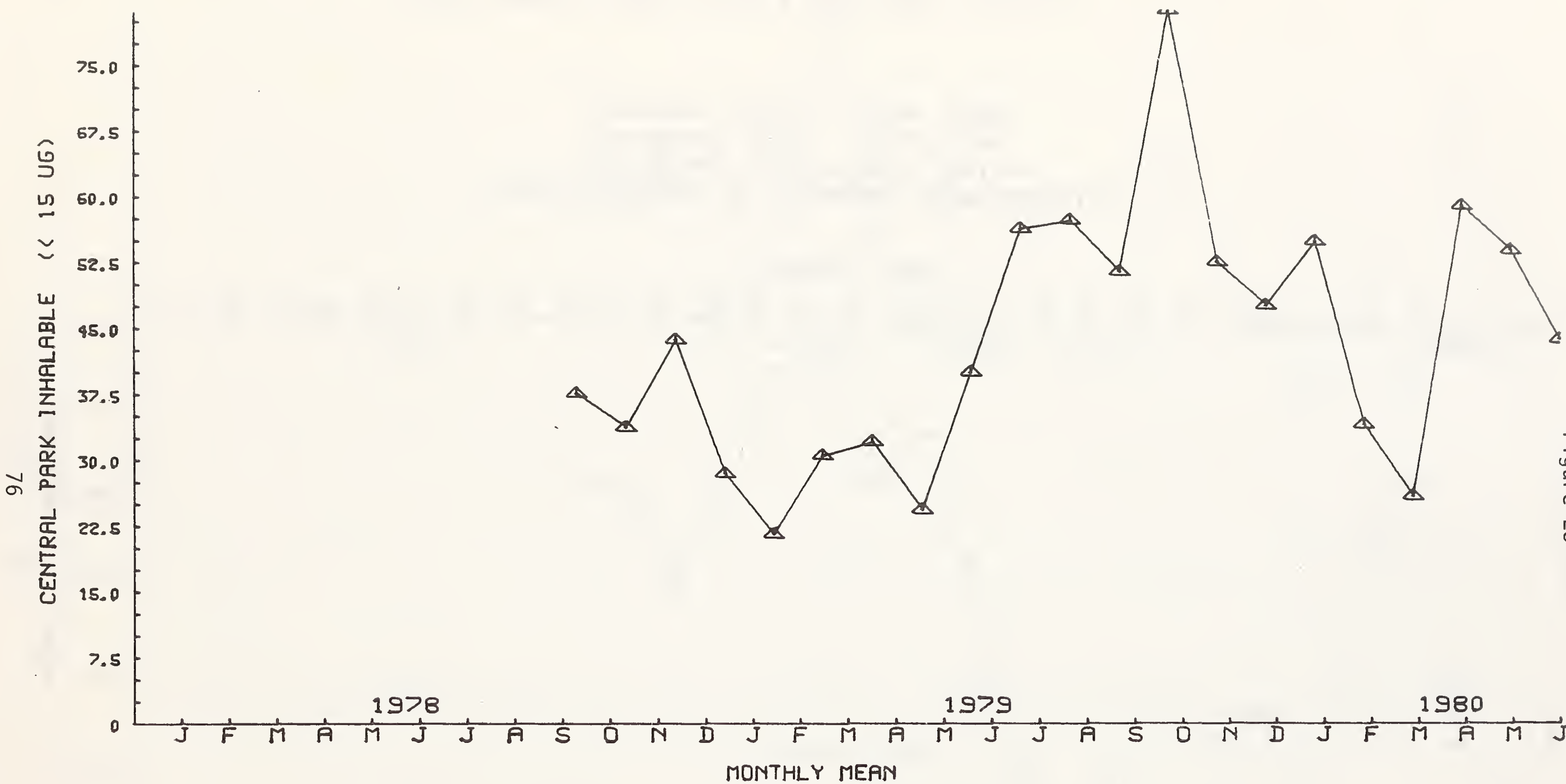



Monthly Mean vs. Coarse Particulate
Micrograms per Cubic Meter
Central Park Billings
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 23




Monthly Mean vs. Inhalable Particulate
Micrograms per Cubic Meter
Central Park Billings
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

On the average, the inhalable particulates contributed the greatest portion of the total concentration of suspended particulates during the winter months. Conversely, the fine particulate fraction of the total was least during the late summer when a greater percentage of large particles occurred.

Table 25 shows a similar comparison of inhalable particulates at the Lockwood School site, although only ten months of data were available for this report. However, some interesting statistics are evident. The concentration of particles less than 2.5 microns varied from 8 $ug/m^3$ in March 1980 to 45 $ug/m^3$ in July 1979. The average concentration was 19 $ug/m^3$. The coarse fraction of the inhalable particulates varied from 0 to 33 $ug/m^3$ (July 1979) with an average of 3 $ug/m^3$ in October, November, and December 1979. The fine fraction constituted about 83 percent of the inhalable particulate concentration at the Lockwood School site, which compares with a value of 39 percent measured at the Central Park site. In Table 24 a calculation was made of the total particulate's average and of three size ranges of fine particles for the same time period as shown in Table 25. The results show higher total particulate concentrations at Central Park (Central Park = 90 and Lockwood School = 63 $ug/m^3$) and much higher values for the coarse fraction at the Central Park site (Central Park = 34 and Lockwood School = 3 $ug/m^3$). However, the fine fraction concentration (particles less than 2.5 microns) showed similar concentrations at both sites (Central Park = 16 and Lockwood School = 19 $ug/m^3$). These data agree with the concept that the concentration of the fine fraction-size particulates is generally the same throughout the area (Billings metropolitan area), whereas the coarse fraction and larger particles tend to be localized and not transported or dispersed throughout the concerned area.

TABLE 25

LOCKWOOD SCHOOL MONTHLY AVERAGE PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Susp. Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Jul 79 | 82 | 45 | 33 | 78 |
| Aug | 76 | 12 | 2 | 15 |
| Sep | 169 | 30 | 1 | 31 |
| Oct | 48 | 17 | 0 | 17 |
| Nov | 52 | 16 | 0 | 16 |
| Dec | 45 | 21 | - | 21 |
| Jan 80 | 24 | -- | -- | -- |
| Feb | 31 | 13 | 6 | 19 |
| Mar | 28 | 8 | 1 | 9 |
| Apr | 66 | 13 | 6 | 22 |
| Average | 63 | 19 | 3 | 23 |

3. Trace Elements

During MAPS, chemical analyses were performed on the high-volume air samples for a variety of trace elements by means of atomic absorption. The laboratory method used a partial digestionprocedure with concentrated nitric acid. The results of these analyses are presented in Tables 26 and 27 for the Lockwood School site and Central Park site, respectively. Shown in the tables are monthly average concentrations of trace elements and the corresponding average concentration of total suspended particulates. In the tables, values shown as zero are actually less than the detection limit of the analysis method.

Monthly averages for arsenic ranged from 0.000 during May 1979 and December 1979 through March 1980 to 0.004 in September 1979. Comparing the arsenic concentrations to those of total suspended particulates, March 1979 also experienced the highest concentration of particulates at the Lockwood School site for that period. The near zero concentrations of arsenic also occurred during the months of the lowest total particulate concentrations.

Concentrations of cadmium did not follow either the total particulate concentrations or the arsenic. Cadmium averages varied from 0.00/ug/m$^3$ during five separate months to 0.004/ug/m$^3$ during November 1979. The average cadimum value was 0.002 ug/m$^3$.

Chromium concentrations were near zero for all months except September 1979 when the highest average particulate concentration occurred. In September, the chromium average was 0.005 ug/m$^3$.

Copper concentrations averaged 0.02 ug/m$^3$ for the year. The month with the highest average was October 1979 (0.15 ug/m$^3$). July 1979, December 1979, and February 1980 had the lowest average concentrations (0.01 ug/m$^3$). The copper concentrations did not follow the total particulate concentrations.

Lead concentrations averaged 0.08 ug/m$^3$ for the year. October and December 1979 and April 1980 had the highest average concentration (0.10 ug/m$^3$), while

TABLE 26

LOCKWOOD SCHOOL MONTHLY AVERAGE TRACE ELEMENT AND PARTICULATE DATA*
(Values in micrograms per cubic meter)

| Month | TSP | Arsenic | Cadmium | Chromium | Copper | Lead | Manganese | Nickel | Vanadium | Nitrate | Sulfate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May 79 | 55 | 0.000 | 0.003 | 0.000 | 0.02 | 0.08 | 0.03 | 0.000 | 0.00 | 1.3 | 5.5 |
| Jun | 91 | 0.002 | 0.003 | 0.000 | 0.02 | 0.06 | 0.05 | 0.003 | 0.00 | 2.2 | 8.8 |
| Jul | 82 | 0.001 | 0.003 | 0.000 | 0.01 | 0.06 | 0.05 | 0.006 | 0.00 | 1.9 | 7.1 |
| Aug | 76 | 0.001 | 0.001 | 0.000 | 0.04 | 0.06 | 0.05 | 0.006 | 0.00 | 1.5 | 8.0 |
| Sep | 169 | 0.004 | 0.001 | 0.005 | 0.02 | 0.09 | 0.09 | 0.003 | 0.00 | 2.2 | 9.1 |
| Oct | 48 | 0.001 | 0.002 | 0.000 | 0.15 | 0.10 | 0.03 | 0.000 | 0.00 | 1.3 | 10.9 |
| Nov | 52 | 0.001 | 0.004 | 0.000 | 0.03 | 0.07 | 0.04 | 0.003 | 0.00 | 1.6 | 12.0 |
| Dec | 45 | 0.000 | 0.003 | 0.000 | 0.01 | 0.10 | 0.03 | 0.003 | 0.00 | 1.0 | 6.7 |
| Jan 80 | 24 | 0.000 | 0.001 | 0.000 | 0.04 | 0.05 | 0.00 | 0.005 | 0.00 | 1.6 | 8.6 |
| Feb | 31 | 0.000 | 0.003 | 0.000 | 0.01 | 0.08 | 0.01 | 0.000 | 0.00 | 2.3 | 9.1 |
| Mar | 28 | 0.000 | 0.001 | 0.000 | 0.02 | 0.07 | 0.01 | 0.000 | 0.00 | 1.0 | 6.9 |
| Apr | 66 | 0.002 | 0.001 | 0.000 | 0.03 | 0.10 | 0.04 | 0.000 | 0.00 | 1.1 | 7.8 |
| Ave. | 64 | 0.001 | 0.002 | 0.000 | 0.02 | 0.08 | 0.04 | 0.002 | 0.0 | 1.6 | 8.5 |

*Collection Method - high volume air sample (glass fiber filters) and atomic absorption analysis

TABLE 27

CENTRAL PARK MONTHLY AVERAGE TRACE ELEMENT AND PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | TSP | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc | Nitrate | Sulfate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jun 78 | 79 | 1.54 | 0.002 | 0.001 | 0.012 | 0.06 | 1.25 | 0.19 | 0.04 | 0.010 | --- | 0.04 | 1.1 | 4.9 |
| Jul | 82 | 1.06 | 0.002 | 0.002 | 0.021 | 0.03 | 1.48 | 0.34 | 0.03 | 0.091 | --- | 0.05 | 1.2 | 6.0 |
| Aug | 109 | 1.41 | 0.001 | 0.001 | 0.019 | 0.03 | 1.77 | 0.35 | 0.03 | 0.007 | --- | 0.03 | 1.4 | 6.8 |
| Sep | 82 | --- | --- | --- | --- | --- | --- | --- | --- | 0.006 | --- | --- | 1.3 | 7.1 |
| Oct | 85 | 0.76 | 0.002 | --- | --- | 0.08 | 1.01 | 0.69 | 0.04 | 0.009 | --- | 0.06 | 1.3 | 6.7 |
| Nov | 66 | 0.63 | 0.002 | 0.001 | --- | 0.06 | 0.72 | 0.41 | 0.04 | 0.005 | --- | 0.05 | 2.2 | 11.2 |
| Dec | 29 | 0.16 | 0.003 | 0.031 | 0.103 | 0.10 | 0.26 | 0.34 | 0.07 | 0.005 | 0.00 | 0.04 | 2.2 | 6.3 |
| | | | | | | | | | | | | | | |
| Jan 79 | 34 | 0.20 | 0.006 | --- | --- | 0.06 | 0.13 | 0.22 | 0.02 | --- | --- | 0.02 | 2.6 | 7.9 |
| Feb | 41 | 0.27 | 0.014 | 0.002 | 0.013 | 0.06 | 0.45 | 0.38 | 0.02 | 0.005 | --- | 0.04 | 3.6 | 9.6 |
| Mar | 70 | 2.84 | 0.000 | 0.001 | 0.001 | 0.04 | 0.85 | 0.31 | 0.03 | 0.002 | 0.00 | 0.10 | 1.3 | 5.3 |
| Apr | 79 | --- | 0.001 | 0.002 | 0.000 | 0.09 | --- | 0.20 | 0.03 | 0.003 | 0.00 | --- | 1.5 | 5.5 |
| May | 95 | --- | 0.001 | 0.002 | 0.000 | 0.07 | --- | 0.19 | 0.05 | 0.007 | 0.01 | --- | 1.6 | 5.2 |
| Jun | 105 | --- | 0.004 | 0.002 | 0.000 | 0.08 | --- | 0.16 | 0.06 | 0.018 | 0.00 | --- | 1.6 | 5.3 |
| Jul | 108 | --- | 0.002 | 0.002 | 0.001 | 0.07 | --- | 0.20 | 0.08 | 0.005 | 0.00 | --- | 1.7 | 6.5 |
| Aug | 121 | --- | 0.001 | 0.002 | 0.004 | 0.21 | --- | 0.22 | 0.11 | 0.012 | 0.00 | --- | 1.6 | 6.5 |
| Sep | 137 | --- | 0.001 | 0.001 | 0.000 | 0.39 | --- | 0.48 | 0.09 | 0.004 | 0.00 | --- | 1.9 | 7.0 |
| Oct | 71 | --- | 0.000 | 0.003 | 0.000 | 0.17 | --- | 0.37 | 0.04 | 0.001 | 0.00 | --- | 1.4 | 6.0 |
| Nov | 73 | --- | 0.001 | 0.002 | 0.000 | 0.24 | --- | 0.25 | 0.03 | 0.006 | 0.00 | --- | 1.6 | 6.5 |
| Dec | 86 | --- | 0.001 | 0.002 | 0.000 | 0.10 | --- | 0.45 | 0.05 | 0.001 | 0.00 | --- | 1.7 | 5.3 |
| | | | | | | | | | | | | | | |
| Jan 80 | 57 | --- | 0.001 | 0.003 | 0.000 | 0.12 | --- | 0.26 | 0.03 | 0.000 | 0.00 | --- | 2.2 | 8.2 |
| Feb | 52 | --- | 0.000 | 0.002 | 0.000 | 0.08 | --- | 0.27 | 0.03 | 0.000 | 0.00 | --- | 2.6 | 6.7 |
| Mar | 66 | --- | 0.025 | 0.002 | 0.000 | 0.07 | --- | 0.14 | 0.03 | 0.000 | 0.00 | --- | 1.5 | 5.6 |
| Apr | 103 | --- | 0.002 | 0.001 | 0.000 | 0.15 | --- | 0.14 | 0.08 | 0.000 | 0.00 | --- | 1.2 | 6.0 |

[a]Collection method - high volume air sampler (glass fiber filters) and atomic absorption analysis
Values presented as zero are actually less

TABLE 28

CENTRAL PARK MONTHLY AVERAGE TRACE ELEMENT DATA
(Values in micrograms per cubic meter)

| Month | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov 78 | 0.24 | --- | 0.004 | --- | 0.01 | 0.23 | 0.42 | 0.01 | --- | --- | 0.03 |
| Dec | 0.23 | 0.002 | 0.004 | --- | 0.02 | 0.22 | 0.36 | 0.01 | --- | --- | 0.03 |
| Jan 79 | 0.41 | 0.001 | 0.003 | --- | 0.02 | 0.27 | 0.36 | 0.02 | --- | --- | 0.03 |
| Feb | 0.46 | 0.001 | 0.004 | --- | 0.02 | 0.49 | 0.36 | 0.03 | --- | --- | 0.04 |
| Mar | 0.53 | 0.002 | 0.003 | --- | 0.01 | 0.64 | 0.23 | 0.03 | --- | --- | 0.02 |
| Apr | 0.82 | 0.002 | 0.003 | --- | 0.06 | 0.99 | 0.17 | 0.04 | ---- | ---- | 0.03 |
| May | 0.85 | 0.002 | 0.003 | --- | 0.01 | 0.85 | 0.16 | 0.03 | --- | --- | 0.03 |
| Jun | 1.72 | 0.002 | 0.002 | --- | 0.04 | 1.99 | 0.23 | 0.07 | --- | --- | 0.03 |
| Jul | 2.06 | 0.001 | 0.003 | 0.360 | 0.03 | 2.23 | 0.28 | 0.07 | 0.024 | --- | 0.05 |
| Aug | 1.88 | 0.002 | --- | 0.078 | 0.12 | 2.34 | 0.34 | 0.10 | 0.094 | --- | 0.04 |
| Sep | 3.68 | 0.004 | 0.010 | 0.044 | 0.10 | 4.20 | 0.68 | 0.15 | 0.058 | 0.07 | 0.09 |
| Oct | 1.43 | 0.002 | --- | --- | --- | 1.32 | 0.51 | 0.07 | 0.053 | 0.08 | 0.06 |
| Nov | 1.42 | 0.002 | --- | --- | --- | 2.05 | 0.50 | --- | 0.034 | --- | 0.09 |
| Dec | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Jan 80 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Feb | 1.13 | 0.001 | 0.000 | 0.000 | 0.04 | 0.94 | 0.60 | 0.04 | 0.003 | 0.00 | 0.06 |
| Mar | 1.39 | 0.000 | 0.000 | 0.000 | 0.05 | 1.14 | 0.40 | 0.05 | 0.000 | 0.00 | 0.03 |
| Apr | 2.23 | 0.001 | 0.000 | 0.000 | 0.06 | 2.53 | 0.28 | 0.09 | 0.000 | 0.00 | 0.04 |

[a]Collection method - membrane air sampler (cellulose filters) and atomic absorption analysis

January 1980 had the lowest average concentration (0.05 ug/m$^3$). Lead values also did not compare well with total particulate concentrations or with the copper concentrations. The Montana ambient standard for lead is 1.5 ug/m$^3$, ninety-day average, not to be exceeded. The federal standard also is 1.5 ug/m$^3$, for a quarter, not to be exceeded. Neither of these standards was approached or exceeded. The highest three-month average was 0.09 ug/m$^3$, well below both standards.

Nickel and vanadium averages were low and in most cases below the detection limit. The highest average nickel value was 0.06 ug/m$^3$ (July and August, 1979). No vanadium average was above 0.00 ug/m$^3$.

Nitrate averages ranged from 1.0 ug/m$^3$ (December 1979 and March 1980) to 2.3 ug/m$^3$ (February 1980). The annual average nitrate value was 1.6 ug/m$^3$. Nitrate values did not correspond to the total particulate concentrations, and no clear seasonal trend was evident.

Sulfate averages ranged from 5.5 ug/m$^3$ in May 1979 to 12.0 ug/m$^3$ in November 1979. Annual average sulfate concentration was 8.5 ug/m$^3$, and appeared to have higher values during the fall and lower values during the late spring and early summer.

Table 27 summarizes similar trace element data for the Central Park site in Billings. Arsenic values averaged slightly higher at Central Park than at Lockwood School. The highest average arsenic value at Central Park was 0.025 ug/m$^3$ (March 1980). Cadmium values were similar at both sites. However, chromium, copper, lead, and nickel values all averaged fairly close to the same at both sites. Sulfate values, on the other hand, were higher at the Lockwood School than at Central Park. The maximum monthly average at Central Park was 11.2 ug/m$^3$ (November 1978). Among the Central Park samples, additional analyses were performed for aluminum, iron, and zinc concentrations during 1978 and early

1979. The maximum iron monthly average was 1.77 ug/$m^3$ (August 1978), while the maximum zinc monthly average was 0.10 ug/$m^3$ (March 1979). Due to the limited sampling period, no defnite trend was established for aluminum, iron, or zinc concentrations.

At the Central Park site, sampling also was performed for trace elements using a membrane sampler and cellulose filters. Analyses were performed on the membrane samples for similar trace elements. The results of those analyses are presented as monthly averages in Table 28. For aluminum, very little correlation was evident between the high-volume samples and the membrane samples. The membrane sample aluminum concentrations were more consistent from month to month, whereas the high-volume samples showed great variation in concentrations. Arsenic values were fairly similar on both sample types. Cadmium concentrations averaged slightly higher on the membrane samples. However, copper concentrations were significantly higher on the high-volume samples. Lead, manganese, and zinc concentrations were fairly similar on the two collection media.

4. Gaseous Pollutants

Sampling was performed for a variety of gaseous compounds at various sites in the Billings area. Results of this sampling are presented in Tables 29 through 36.

Table 29 summarizes the ozone data collected at the Central Park and Twenty-seventh Street and Montana sampling sites. Sampling at the Central Park site was performed for early two years during MAPS. The maximum one-hour average concentration recorded was 0.145 parts per million (ppm), which compares to the federal primary one-hour standard of 0.12 ppm, not to be exceeded more than one

TABLE 29

BILLINGS AREA OZONE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Central Park (Jul 78 - May 80) | 27th and Montana (Jan - Jul 78) |
|---|---|---|
| 1-hour maximum (high) | 0.145 | 0.120 |
| 1-hour maximum (2nd high) | 0.110[b] | 0.120[a] |
| Average* | 0.020 | 0.021 |
| No. of Readings | 14560 | 4055 |

*Time period of average varies by site
[a]Occurred on same day as high reading. Second high on separate day was 0.08 ppm.
[b]Occurred during separate year. Second high during same year was 0.105 ppm.

TABLE 30

BILLINGS AREA CARBON MONOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | 27th & Montana (Jan - Jun 78) | Fairgrounds (Dec 78, Jul, Aug 79) |
|---|---|---|
| 1-hour maximum | 15.9 | 6.6 |
| 8-hour maximum | 8.4 | 2.3 |
| Average* | 1.6 | 0.7 |
| No. of Readings | 1808 | 819 |

*Time period of average varies by site

TABLE 31

BILLINGS AREA TOTAL HYDROCARBON DATA SUMMARY[a]
(Values in parts per million)

| Averaging Time | Central Park (Jul 78 - Mar 79) | 27th and Montana (Jan - May 78) |
|---|---|---|
| 3-hour maximum* | 7.1 | 6.4 |
| Average+ | 3.79 | 3.76 |
| No. of Readings | 1845 | 1573 |

+Time period of average varies by site
*3-hour average from 6 to 9 a.m.
[a]Note federal ambient standard is for non-methane hydrocarbons (see Table 3)

TABLE 32

BILLINGS AREA NITROGEN DIOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Central Park (Jun 78-May 80) | 27th and Montana (Jan - Mar 78) |
|---|---|---|
| 1-hour maximum | 0.147 | 0.175 |
| Average* | 0.015 | 0.037 |
| No. of Readings | 7834 | 658 |

*Time period of average varies by site

TABLE 33

BILLINGS AREA OXIDES OF NITROGEN DATA SUMMARY
October 1979 - January 1980

Central Park Site
(Values in parts per million)

| Averaging Time | Nitric Oxide (NO) | Nitrogen Dioxide ($NO_2$) | Oxides of Nitrogen (NOx) |
|---|---|---|---|
| 1-hour maximum | 0.283 | 0.147 | 0.316 |
| Average* | 0.032 | 0.018 | 0.051 |

*Average of approximately three months data

TABLE 34

BILLINGS AREA SULFUR DIOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Lockwood School (Apr79-Jun 80) | Central Park (Jun78-May80) | 27th & Montana (Jan-Jul78) | Laurel Farm[a] (Jan78-Jun80) |
|---|---|---|---|---|
| 1-hour maximum (high) | 0.435 | 0.375 | 0.170 | 0.660 |
| 1-hour maximum (2nd high) | 0.350 | 0.245 | 0.150 | 0.660 |
| 3-hour maximum (high) | 0.220 | 0.210 | 0.113 | 0.580 |
| 3-hour maximum (2nd high) | 0.219 | 0.192 | 0.067 | 0.480 |
| 24-hour maximum (high)+ | 0.076 | 0.091 | 0.020 | 0.290 |
| 24-hour maximum (2nd high)+ | 0075 | 0.069 | 0.010 | 0.270 |
| Average* | 0.019 | 0.010 | 0.000 | 0.028 |
| No. of Reading | 8634 | 13,313 | 2504 | 10,428 |

*Time period of average varies by site
+Midnight to midnight
[a]State monitoring results only (county had monitor at same site temporatily)

TABLE 35

CENTRAL PARK MONTHLY AVERAGE AIR QUALITY SUMMARY

| Month | Total Susp. Particulates+ | Suspended Part. 2.5 microns+ | Suspended Part. 2.5 to 15 microns+ | Sulfur Dioxide* | Nitrogen Dioxide* | Total Hydrocarbons* | Ozone |
|---|---|---|---|---|---|---|---|
| Jun 78 | 79 | --- | --- | 0.002 | 0.011 | --- | --- |
| Jul | 82 | --- | --- | 0.006 | --- | 2.27 | 0.027 |
| Aug | 109 | --- | --- | 0.008 | 0.017 | 2.27 | 0.016 |
| Sep | 82 | 25 | 13 | 0.011 | --- | 2.75 | 0.014 |
| Oct | 85 | 20 | 14 | 0.012 | 0.024 | --- | 0.010 |
| Nov | 66 | 22 | 21 | 0.018 | 0.010 | 2.37 | 0.008 |
| Dec | 29 | 14 | 14 | 0.012 | 0.002 | 2.30 | 0.015 |
| Jan 79 | 34 | --- | --- | 0.021 | --- | 2.38 | 0.017 |
| Feb | 41 | 28 | 2 | 0.021 | 0.025 | 2.50 | 0.017 |
| Mar | 70 | 19 | 13 | 0.009 | --- | 3.96 | 0.017 |
| Apr | 79 | 15 | 9 | 0.006 | 0.015 | --- | 0.027 |
| May | 95 | 20 | 20 | 0.005 | --- | --- | 0.037 |
| Jun | 105 | 20 | 36 | 0.004 | --- | --- | 0.037 |
| Jul | 108 | 13 | 43 | 0.010 | --- | --- | 0.035 |
| Aug | 121 | 14 | 37 | 0.009 | 0.012 | --- | 0.031 |
| Sep | 137 | 22 | 58 | --- | 0.017 | --- | 0.021 |
| Oct | 71 | 18 | 34 | --- | 0.018 | --- | 0.015 |
| Nov | 73 | 15 | 32 | --- | 0.018 | --- | 0.015 |
| Dec | 86 | 12 | 42 | 0.009 | 0.027 | --- | 0.014 |
| Jan 80 | 57 | 18 | 17 | 0.014 | 0.018 | --- | 0.017 |
| Feb | 52 | 12 | 12 | 0.011 | 0.018 | --- | 0.015 |
| Mar | 66 | 24 | 34 | 0.009 | 0.009 | --- | 0.015 |
| Apr | 103 | 14 | 39 | 0.009 | 0.010 | --- | 0.020 |
| May | 109 | 10 | 33 | 0.007 | 0.009 | --- | 0.021 |

+Values in micrograms per cubic meter
*Values in parts per million

TABLE 36

27TH AND MONTANA MONTHLY AVERAGE AIR QUALITY SUMMARY

| Month | Sulfur Dioxide* | Nitrogen Dioxide* | Total Hydrocarbons* | Carbon Monoxide* | Ozone* |
|---|---|---|---|---|---|
| Jan 78 | 0.00 | 0.039 | 4.49 | 3.0 | 0.014 |
| Feb | 0.00 | 0.039 | 4.01 | 2.2 | 0.019 |
| Mar | 0.00 | 0.015 | 3.95 | 2.0 | 0.018 |
| Apr | 0.00 | --- | 3.82 | 1.1 | 0.022 |
| May | 0.00 | --- | 3.09 | 1.4 | 0.025 |
| June | 0.00 | --- | --- | 1.3 | 0.023 |
| Jul | 0.00 | --- | --- | --- | 0.029 |

*Values in parts per million

day per year. The Montana one-hour standard is 0.10 ppm, not to be exceeded more than once per year. Since both the Montana and federal standards allow at least one excursion (since the federal standard allows one day of excursions, hypothetically 24 excursions could be allowed), Table 29 lists the second highest one-hour ozone concentrations. At Central Park, the second-highest one-hour concentration was 0.110 ppm, which occurred not only on a separate day, but also during a separate year. Therefore, it would not constitute a violation. The second-highest one-hour concentration during the same year was 0.105 ppm, which is in slight excess of the Montana standard. The average ozone concentration at Central Park for the two-year period was 0.02 ppm.

At the 27th and Montana sampling site, ozone data were available only for a seven-month period during MAPS. The maximum one-hour concentration was 0.120 ppm. The second-highest one-hour concentration also was 0.120, but it occurred during the same day. The second highest concentration would constitute a violation of the Montana ambient standard. The second highest one-hour ozone concentration on a separate day was 0.08 ppm, while the average concentration for the seven-month period was 0.021 ppm. The accuracy of this data, however, is probably less than that of Central Park due to calibration difficulties.

Tables 35 and 36 list the monthly average ozone concentrations at the Central Park and 27th and Montana sites along with various other pollutants. The Central Park data indicate highest monthly average concentrations during the summer (May-July 1979), while the lowest average concentrations occurred during the late fall and early winter (October-December 1978 and 1979).

Table 30 summarizes the carbon monoxide data for the 27th and Montana and Fairgrounds sampling sites. The 27th and Montana sampler was operated from January through June of 1978, and the max mum one-hour concentration of carbon

monoxide at the 27th and Montana site was 15.9 ppm. This compares to both the federal ambient standard of 35 ppm (not to be exceeded more than once per year) and the Montana ambient standard of 23 ppm (not to be exceeded more than once per year). The maximum eight-hour average carbon monoxide concentration at the 27th and Montana site was 8.4 ppm, which also was below the federal and Montana ambient standard of 9.0 ppm (not to be exceeded more than once per year). The average carbon monoxide concentration for the six-month period was 1.6 ppm.

Table 36 lists the monthly average carbon monoxide concentrations at the 27th and Montana site. Because of the short sampling period, no seasonal trend is available.

Table 31 summarizes the total hydrocarbon data for the Central Park and 27th and Montana sites. The Central Park site was operated from July 1978 through March 1979. The maximum three-hour concentration for the hours of 0600 to 0900 was 7.1 ppm. The federal ambient guideline is for non-methane hydrocarbons only. Therefore, a direct comparison with the standard is not possible using these data. The average concentration over the entire sampling period was 3.79 ppm.

The 27th and Montana sampler was operated from January through May 1978. The maximum three-hour concentration for the 0600 to 0900 time period was 6.4 ppm, and the average concentration over the entire sampling period was 3.76 ppm.

Table 35 summarizes the monthly averages of total hydrocarbons at the Central Park site. Very little variation from month to month occurred, and no trend was evident from the short period sampled. Likewise, Table 36 summarizes the same data for the 27th and Montana site. Once again, little can be determined from the short time period as to seasonal trends.

Table 32 summarizes the nitrogen dioxide data from the Central Park and 27th and Montana sites. Data were collected at the Central Park site from June 1978 through May 1980. The maximum one-hour concentration at the Central Park site was 0.147 ppm, which compares with the Montana ambient standard of 0.30 ppm (not to be exceeded more than once per year). The average concentration over the two years of data collection was 0.015 ppm. The federal and Montana annual ambient standard is 0.05 ppm.

The 27th and Montana sampler was operated from January through March 1978. The maximum one-hour concentration was 0.175 ppm. The average concentration over the three-month period was 0.037 ppm.

Table 35 lists the monthly average nitrogen dioxide concentrations at the Central Park site. Missing data throughout the period make any trend difficult to establish. However, the data do indicate highest concentrations of nitrogen dioxide in the late autumn and early winter with lowest concentrations during the summer.

Table 33 also summarizes the nitrogen dioxide, oxides of nitrogen, and nitric oxide data for the Central Park site. On the average, nitric oxide composes about two-thirds of the oxides of nitrogen, with nitrogen dioxide comprising the remaining one-third. The maximum one-hour nitric oxide concentration was 0.283 ppm compared to 0.147 ppm for nitrogen dioxide. The overall average nitric oxide concentration was 0.032 ppm compared to 0.018 ppm for nitrogen dioxide.

Table 34 summarizes the sulfur dioxide data collected in the Billings area during MAPS. (Four stations were operated for varying time periods.) The Lockwood School station was operated from April 1979 through June 1980. The maximum and second-highest one-hour concentrations at the Lockwood School were

0.435 and 0.350 ppm, respectively, which compares with the Montana ambient one-hour standard of 0.50 ppm, not to be exceeded more than eighteen times in twelve consecutive months. The three-hour maximum sulfur dioxide concentration at the Lockwood School was 0.220 ppm, which compares with the federal secondary standard of 0.50 ppm, not to be exceeded more than once per year. The maximum twenty-four hour concentration was 0.076 ppm, which compares with the federal primary standard of 0.14 ppm and the Montana standard of 0.10 ppm, not to be exceeded more than once per year. The average concentration at the Lockwood School site over the sampling period was 0.019 ppm. This compares with the federal annual standard of 0.03 ppm and the Montana standard of 0.02 ppm. No excursions of any of the federal or Montana sulfur dioxide ambient standards were recorded at the Lockwood School station.

The Central Park sampler was operated during MAPS from June 1978 through May 1980. The maximum and second highest one-hour concentrations of sulfur dioxide were 0.375 and 0.245 ppm, respectively. The maximum three-hour concentration was 0.210 ppm, the corresponding maximum twenty-four hour concentration was 0.091 ppm, and the overall average concentration during the sampling period was 0.010 ppm. No excursions of any Montana or federal sulfur dioxide standards were recorded at the Central Park station.

At the 27th and Montana station, which had sulfur dioxide sampled from January through July 1978, even lower concentrations were measured. The maximum one-hour, three-hour, and twenty-four hour concentrations were 0.170, 0.113, and 0.020 ppm, respectively. The average concentration during the sampling period was 0.000 ppm.

At the Laurel Farm Station, operated during MAPS from January 1978 through June 1980, much higher concentrations of sulfur dioxide were recorded. The

maximum one-hour, three-hour, and twenty-four hour sulfur dioxide concentrations measured were 0.660, 0.580, and 0.290 ppm, respectively. The second-highest respective concentrations measured were 0.660, 0.480, and 0.270 ppm. Among these, only the twenty-four hour second highest concentration constituted a violation (occurred during same year) of both the federal primary and Montana ambient standards. The three-hour federal secondary standard of 0.50 ppm was not exceeded by the second highest concentration. The second-highest one-hour concentration of 0.660 ppm did exceed the Montana one-hour standard. However, eighteen excursions are allowed in twelve consecutive months. Only eight excursions of the Montana one-hour standard were recorded in the two and one-half years of sampling. The average concentration at the Laurel Farm site over the entire sampling period was 0.028 ppm.

Table 35 lists the monthly average sulfur dioxide concentrations at the Central park site. Highest average concentrations were recorded during the winter months (January, February), whereas the lowest concentrations were recorded during June.

## C. SUMMARY AND CONCLUSIONS

MAPS has provided valuable data on air pollution levels found in the Billings area. Data were collected on concentrations of total suspended particulates, inhalable particulates, trace elements, and gaseous pollutants. Total suspended particulate data showed concentrations in excess of the federal primary standard at one location and the federal secondary and Montana standard at several locations. Seasonal trends varied from site to site with little pattern evident.

Although no federal or Montana standard has been adopted, fine particulate data showed interesting trends and overall averages. Generally, the fine fraction contributed the most to the total inhalable particulate levels during the winter with the least contribution during the late summer. The average fine fraction concentration was 18 $ug/m^3$, whereas the average coarse fraction varied from site to site.

Trace element data generally revealed low levels of all elements analyzed. Variations of concentrations of trace elements within the city from site to site were evident. No ambient standards were exceeded.

Ozone data collected at two sites in Billings showed levels near the federal one-hour standard, but in slight excess of the Montana standard at both locations. Lowest concentrations occurred during the late fall and early winter with highest concentrations during the summer.

Carbon monoxide data for two locations in the Billings area were below both the federal and Montana standards. no seasonal trend was apparent. Data were collected on the concentration of total hydrocarbons; however, as the federal guideline is for non-methane hydrocarbons, no comparison could be made. Nitrogen dioxide data collected at two locations showed concentrations below both federal and Montana ambient standards. Highest concentrations of nitrogen dioxide occurred during the late autumn and early winter, with lowest concentations during the summer.

Sulfur dioxide concentrations were measured at four stations during MAPS. Concentrations were below the federal and Montana standards at all stations except the Laurel Farm station, which had concentrations recorded in excess of the one-, three-, and twenty-four hour Montana and federal standards.

# IV. MISSOULA

This chapter summarizes the ambient air quality data collected in the city of Missoula and some of the surrounding areas. Data on total suspended particulates, sulfur dioxide, nitrogen dioxide, total hydrocarbons, carbon monoxide, ozone, and fine particulates are discussed.

The elevation of the Missoula area is approximately 3200 feet above sea level. The city of Missoula is located in the center of two major valleys, which have a major influence on local meteorological conditions. The Continental Divide, 70 miles east of Missoula, and the Bitterroot Range, 20 miles southwest, significantly influence the area's meteorology. The area experiences frequent temperature inversions that tend to elevate concentrations of trapped pollutants.

The major industrial activities in the area are wood-product related. A pulp and paper mill, two plywood plants, a particle board plant, and a number of sawmills all contribute to the air pollution of the area. Automobiles and home heating devices also are a concern because of heavy traffic and the great number of homes now using wood burning stoves and fireplaces.

## A. METHODOLOGY

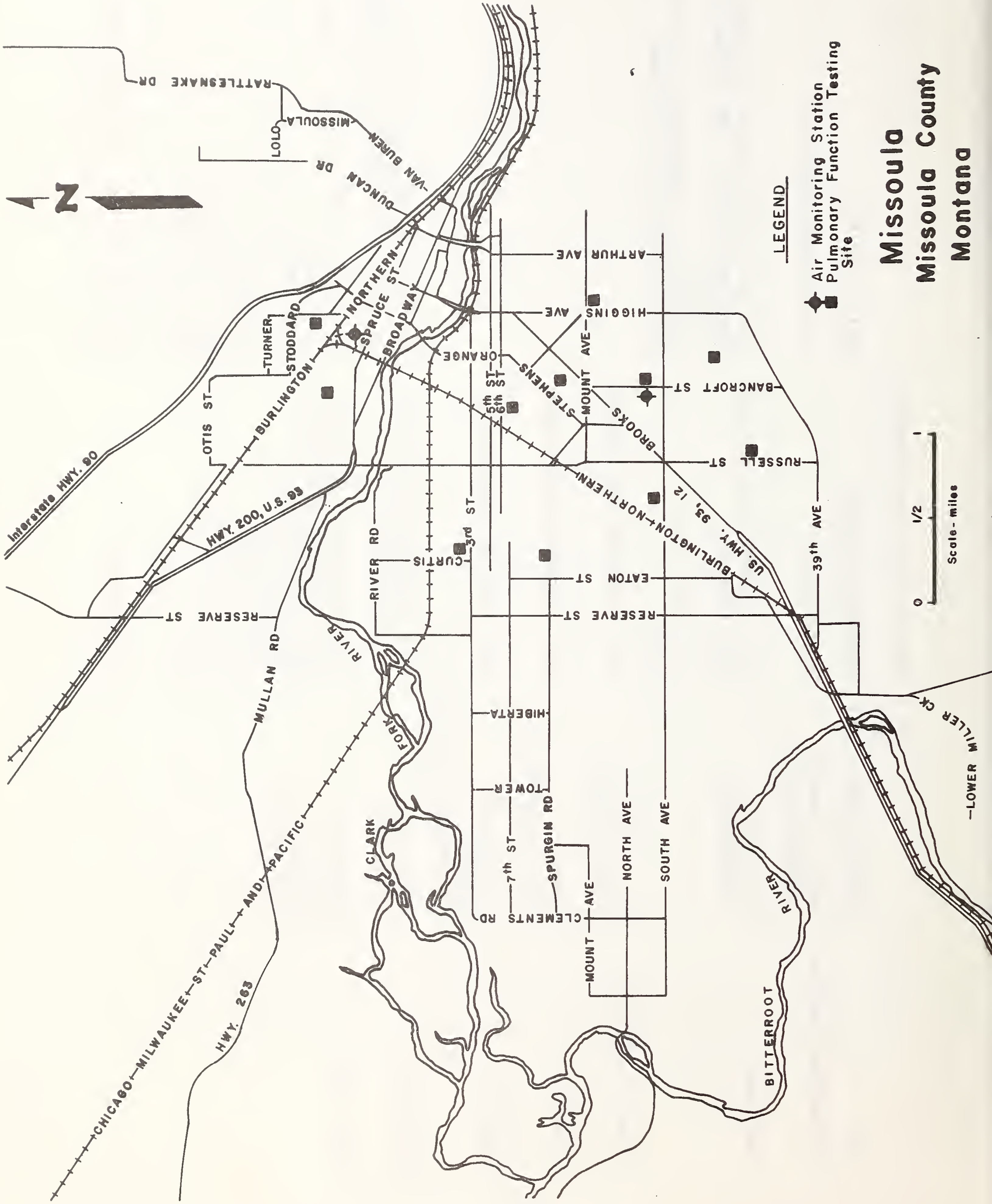
Prior to MAPS, the Air Quality Bureau and the Missoula City-County Health Department operated several ambient air monitoring stations in and around Missoula. With the advent of MAPS, the number of stations and air pollutants monitored was increased. Primary emphasis of the MAPS air quality monitoring was placed

TABLE 37

MISSOULA SAMPLING SITES AND PARAMETERS

| Site | Location (Area type) | Parameters Sampled | Analysis Method |
|---|---|---|---|
| Malfunction Junction | Central Missoula (commercial) | Carbon Monoxide | Nondispersion Infra-red |
| Courthouse | NE Missoula (commercial) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements | Atomic Absorption - High Volume Sair Samples |
| | | Fine Particulates | Gravimetric - Dichotomous Air Sampler |
| | | Pollen | Gravity Collection Slide Count |
| Johnson Bell Field | NW of Missoula (rural-airport) | Total Suspended Particulates | |
| Bonner I | Bonner (rural-industrial) | Total Suspended Particulates | |
| Rose Park | Southcentral Missoula (residential-commercial) | Total Suspended Particulates | |
| McLeod Park | W. Missoula (commercial) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Fine Particulates | Gravimetric - Dichotomous Air Sampler |
| Lions Park | Southcentral Missoula (commercial, Residential) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Total Suspended Particulates | Beta Counter |
| | | Scattering Coefficient | Nephelometer |
| | | Carbon Monoxide | Nondispersive Infra-red |
| | | Sulfur Dioxide | Coulometric |
| | | Nitrogen Dioxide | Chemiluminescence |
| | | Total Hydrocarbons | Flame Ionization |
| | | Ozone | Chemiluminescence |
| | | Trace Elements | Atomic Absorption - High Volume Air Samples |
| | | Trace Elements | Atomic Absorption - Membrane Samples |
| | | Pollen | Gravity Collection-Slide Count |

Figure 24


LEGEND
Air Monitoring Station
Pulmonary Function Testing Site
Missoula
Missoula County
Montana
0
1/2
1
Scale - miles
N
RATTLESNAKE DR
MISSOULA
LOLO
VAN BUREN
DUNCAN DR
ARTHUR AVE
HIGGINS AVE
BANCROFT ST
RUSSELL ST
39th AVE
EATON ST
RESERVE ST
MOUNT AVE
BROOKS
STEPHENS
ORANGE
5th ST
6th ST
3rd ST
CURTIS
RIVER RD
HIBERTA
TOWER
7th ST
SPURGIN RD
CLEMENTS RD
NORTH AVE
SOUTH AVE
MOUNT AVE
NORTHERN
SPRUCE ST
BROADWAY
STODDARD
TURNER
OTIS ST
BURLINGTON
BURLINGTON NORTHERN
US. HWY. 93, 12
Interstate HWY. 90
HWY. 200, U.S. 93
MULLAN RD
CLARK FORK RIVER
BITTERROOT RIVER
CHICAGO MILWAUKEE ST. PAUL AND PACIFIC
HWY. 263
LOWER MILLER CK

on the areas of greatest population exposure, i.e., central Missoula. Table 37 lists the various sampling sites operated during MAPS in the Missoula area. These sites also are shown in Figure 24. Table 37 also lists the parameters sampled, the analysis method used in obtaining the data, and the area type. Carbon monoxide was monitored at a site called "Malfunction Junction" (junction of Russell, South, and Brooks Streets in central Missoula). The site is located in a commercial setting. On the roof of the Missoula City-County Courthouse, in downtown Missoula, monitoring was conducted for total and inhalable particulates. Johnson-Bell Field was the site of some total suspended particulate monitoring northwest of Missoula. Particulate monitoring also was conducted during MAPS at Bonner, east of Missoula. In southcentral Missoula at Rose Park, monitoring was conducted for particulates. In western Missoula, monitoring was conducted at McLeod Park for total and fine particulates. At Lions' Park in southcentral Missoula, monitoring was conducted for a variety of gaseous pollutants and particulates.

The data are presented in this chapter by air pollutant. Comparisons are made with the Montana Ambient Air Quality Standards (MAAQS) and the National Ambient Air Quality Standards (NAAQS) listed in Tables 2 and 3. The national or federal standards include both the primary and secondary standards.

## B. PRESENTATION OF RESULTS

### 1. Total Suspended Particulates

Total suspended particulate concentrations as measured by high-volume air samplers are summarized in Tables 38 and 39. Table 38 lists the highest, second-highest, and third-highest concentrations of particulates at each site measured during the time periods shown. The second-highest and third-highest concentrations are shown in addition to the highest as the Montana and federal ambient standards allow one excursion of the twenty-four hour standard during a year without a violation occurring. The second excursion at the same site

TABLE 38

MISSOULA AREA TOTAL SUSPENDED PARTICULATE SUMMARY
(Values in micrograms per cubic meter)

| Site | Maximum Readings High | 2nd High | 3rd High | Arithmetic Mean | Std. Dev. | Geometric Mean | Std. Dev. | No. of Obs. | Time Period |
|---|---|---|---|---|---|---|---|---|---|
| Lions Park | 676 | 606 | 503 | 104 | 70 | 80 | 1.8 | 811* | Jan 78 - May 80 |
| McLeod Park | 407 | 330 | 323 | 120 | 68 | 102 | 1.7 | 110 | Feb 79 - June 80 |
| Rose Park | 383 | 317 | 275 | 97 | 56 | 82 | 1.8 | 366* | Oct 78 - June 80 |
| Bonner 1 | 166 | 166 | 154 | 71 | 41 | 58 | 1.8 | 55 | Jan 78 - Dec 78 |
| Johnson-Bell Field | 320 | 291 | 286 | 77 | 56 | 53 | 2.0 | 346* | Jan 78 - Dec 78 |
| Courthouse Roof | 390 | 358 | 336 | 94 | 49 | 76 | 1.7 | 799* | Jan 78 - May 80 |

*Sampling frequency greater than standard every sixth day schedule

TABLE 39

MISSOULA AREA MONTHLY AVERAGE PARTICULATE LEVELS
(Values in micrograms per cubic meter)

| Month | Lions Park Max | Lions Park Ave | McLeod Park Max | McLeod Park Ave | Rose Park Max | Rose Park Ave | Bonner 1 Max | Bonner 1 Ave | Johnson-Bell Field Max | Johnson-Bell Field Ave | Courthouse Roof Max | Courthouse Roof Ave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 78 | 327 | 116 | | | | | 99 | 51 | 120 | 48 | 175 | 94 |
| Feb | 606 | 169 | | | | | 130 | 76 | 154 | 62 | 270 | 119 |
| Mar | 676 | 226 | | | | | 166 | 100 | 151 | 72 | 390 | 156 |
| Apr | 172 | 76 | | | | | 58 | 51 | 78 | 37 | 158 | 72 |
| May | 99 | 61 | | | | | 50 | 34 | 86 | 44 | 104 | 64 |
| June | 131 | 76 | | | | | 84 | 56 | 165 | 93 | 143 | 82 |
| July | 113 | 65 | | | | | 129 | 76 | 233 | 111 | 140 | 73 |
| Aug | 118 | 69 | | | | | 152 | 75 | 282 | 116 | 204 | 89 |
| Sep | 142 | 70 | | | | | 154 | 68 | 187 | 69 | 163 | 83 |
| Oct | 197 | 118 | | | 234 | 117 | 166 | 128 | 320 | 143 | 250 | 132 |
| Nov | 189 | 93 | | | 244 | 108 | 106 | 60 | 286 | 81 | 232 | 1111 |
| Dec | 159 | 71 | | | 170 | 86 | 88 | 57 | 123 | 49 | 142 | 68 |
| | | | | | | | | | | | | |
| Jan 79 | 221 | 108 | -- | -- | 261 | 137 | | | | 235 | 122 | |
| Feb | 213 | 104 | 150 | 93 | 151 | 93 | | | | 160 | 86 | |
| Mar | 419 | 170 | 283 | 157 | 317 | 139 | | | | 267 | 116 | |
| Apr | 135 | 83 | 143 | 79 | 117 | 68 | | | | 130 | 72 | |
| May | 134 | 75 | -- | -- | 123 | 66 | | | | 167 | 77 | |
| June | 122 | 72 | -- | -- | 110 | 70 | | | | 178 | 98 | |
| Jul | 162 | 74 | -- | -- | 132 | 64 | | | | 155 | 78 | |
| Aug | 111 | 69 | -- | -- | 109 | 57 | | | | 148 | 79 | |
| Sep | 155 | 94 | 323 | 175 | 130 | 77 | | | | 154 | 82 | |
| Oct | 179 | 96 | 164 | 101 | 97 | 74 | | | | 126 | 81 | |
| Nov | 266 | 125 | 208 | 135 | 211 | 140 | | | | 252 | 118 | |
| Dec | 265 | 130 | 202 | 108 | 209 | 114 | | | | 204 | 94 | |
| | | | | | | | | | | | | |
| Jan 80 | 321 | 135 | 226 | 128 | 234 | 134 | | | | 219 | 96 | |
| Feb | 503 | 202 | 407 | 166 | 383 | 163 | | | | 358 | 145 | |
| Mar | 300 | 105 | 330 | 122 | 248 | 105 | | | | 140 | 89 | |
| Apr | -- | -- | -- | -- | -- | -- | | | | -- | -- | |
| May | 121 | 68 | 110 | 79 | 97 | 59 | | | | 163 | 72 | |
| Jun | -- | -- | 118 | 82 | 106 | 61 | | | | -- | -- | |

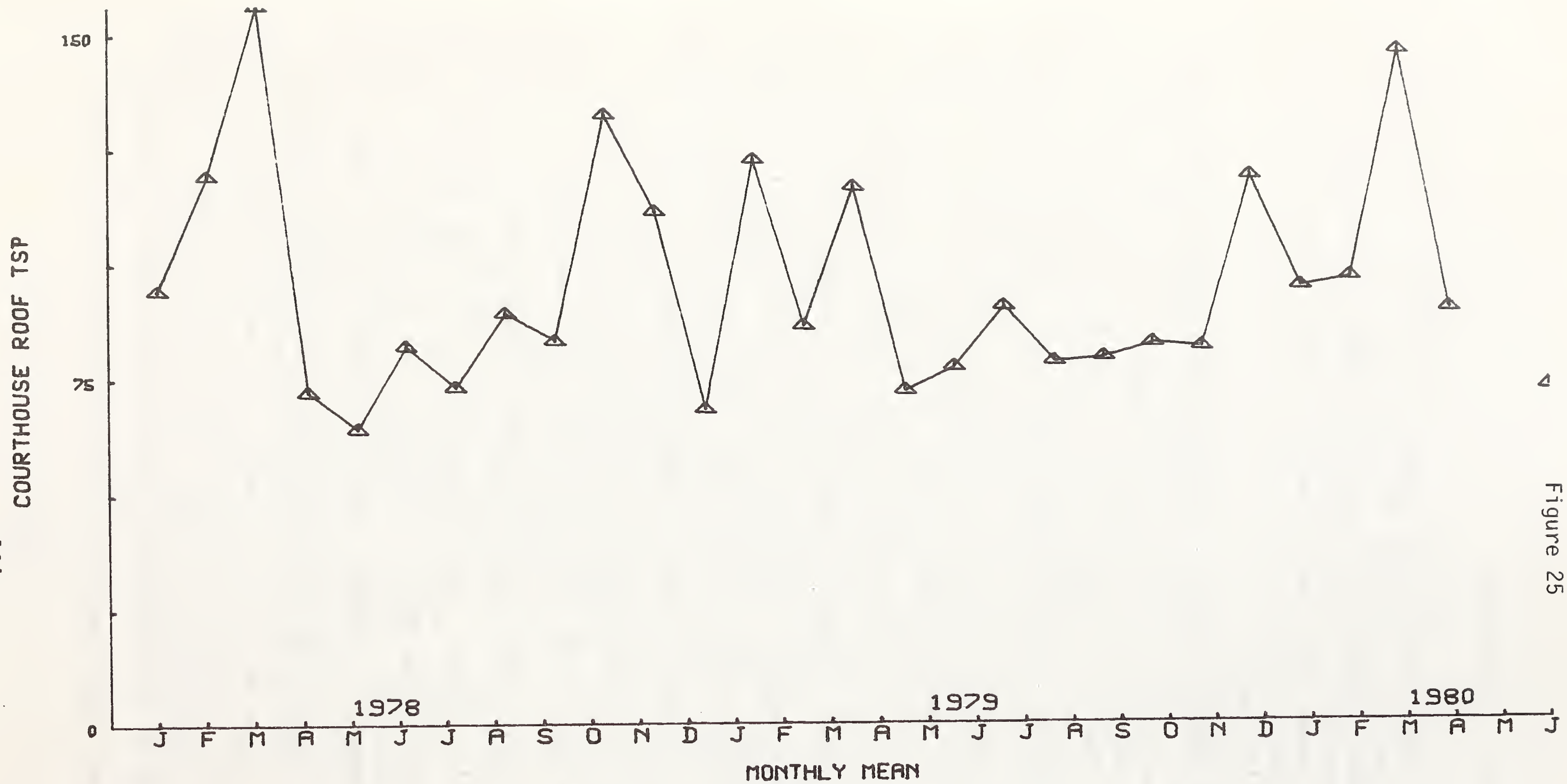
constitutes a violation of the standard. Among the six sites shown in Table 38, concentrations exceeding the twenty-four hour federal primary standard of 250 micrograms per cubic meter (ug/m$^3$) occurred at the Lions' Park, McLeod Park, Schilling Street, Rose Park, Johnson-Bell Field, and Courthouse sites. The second-highest concentration at these same sites also exceeded the federal primary standard. However, a second excursion does not automatically constitute a violation of the standard as both excursions must occur within the same year. In the case of these sites, all the second- or third-highest concentrations, which also exceeded the federal primary standard, occurred during the same twelve consecutive months. Similarly, the federal secondary twenty-four hour standard of 150 ug/m$^3$ was exceeded by the highest and second-highest at all six sampling sites. The highest twenty-four hour particulate concentration measured was 676 ug/m$^3$, which occurred at the Lions' park site. The Montana twenty-four hour standard of 200 ug/m$^3$ was exceeded at Lions' Park, McLeod Park, Rose Park, Johnson-Bell Field, and Courthouse sites. Second excursions of the Montana standard also occurred at the same five sampling sites.

Table 38 also lists the arithmetic mean, arithmetic standard deviation, geometric mean, geometric standard deviation, and number of observations taken. Both the arithmetic and geometric means are listed in Table 38, as the Montana annual standard is based on an arithmetic mean of any twelve consecutive months, whereas the federal primary and secondary annual standards are based on a geometric mean of any twelve consecutive months. The federal primary annual standard of 75 ug/m$^3$ was exceeded at the Lions' Park, McLeod Park, Rose Park, and Courthouse sites during the periods sampled under MAPS. The geometric means presented in Table 38 are in some cases means over more than a year's period. Therefore, these excursions do not necessarily constitute violations. Likewise

the federal secondary annual standard was exceeded at the same four sampling sites. The Montana annual standard of 75 ug/$m^3$ (arithmetic) was exceeded at all the sites, except the Bonner site, and the maximum arithmetic mean occurred at the McLeod Park site (120 ug/$m^3$).

Table 39 lists the monthly arithmetic average total suspended particulate concentrations measured at the six sites in the Missoula area. Also listed are the maximum twenty-four hour concentrations of particulates for each month. These same monthly averages for the Courthouse and Lions' park sites are shown in Figures 25 and 26, respectively. In the figures, monthly averages were not plotted if less than four samples were available for averaging. At the Lions' Park site, the trend in Table 39 and Figure 19 shows highest concentrations in the winter and early spring (January through March) and lowest concentrations in the summer (June through August). The overall trend shows a gradual increase in total suspended particulate levels at the Lions' Park site. The McLeod Park site has too little or intermittant data to show any evidence of a trend. On the contrary, the Rose Park data describe a trend similar to that of Lions' Park, with highest averages in the winter and early spring and lowest averages in the summer. The overall trend at Rose Park also shows a gradual increase in total particulate levels. Bonner I and Johnson-Bell Field sites again have only one year's data available during MAPS. The trend at the two sites shows lowest averages during the summer, but highest monthly averages occur at random periods throughout the year. Table 30 and Figure 25 present the monthly averages for the Courthouse site. Since the site is an urban site somewhat similar to Lions' Park, a trend similar to that shown at Lions' Park would be expected. As shown in Figure 25, the trend at the Courthouse site is toward highest averages of particulates during late winter and early spring and lowest averages during

Figure 25




Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Courthouse Roof Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

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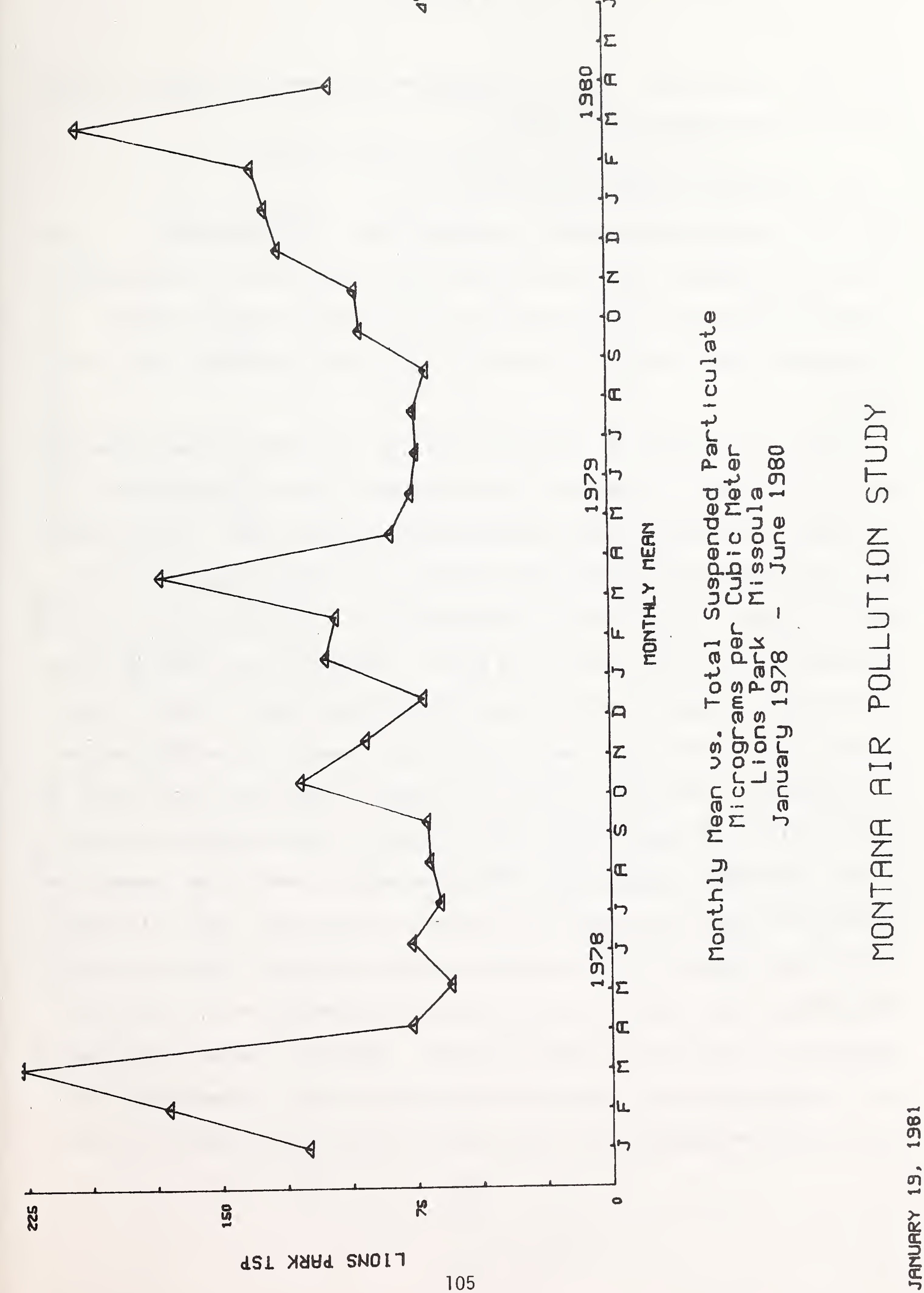
Figure 26


LIONS PARK TSP
0
75
150
225
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
1978
1979
1980
MONTHLY MEAN
Monthly Mean vs. Total Suspended Particulate
Micrograms per Cubic Meter
Lions Park Missoula
January 1978 - June 1980
MONTANA AIR POLLUTION STUDY
JANUARY 19, 1981

the summer. The overall trend, as in the other data presented, shows a gradual increase in total particulate levels.

2. Inhalable Suspended Particulates

During the MAPS monitoring program, a network of samplers was established throughout the state to measure the concentration of inhalable suspended particulates. See Chapter II for a description of this network. Three samplers were located in Missoula at McLeod Park, Courthouse, and Lions' Park.

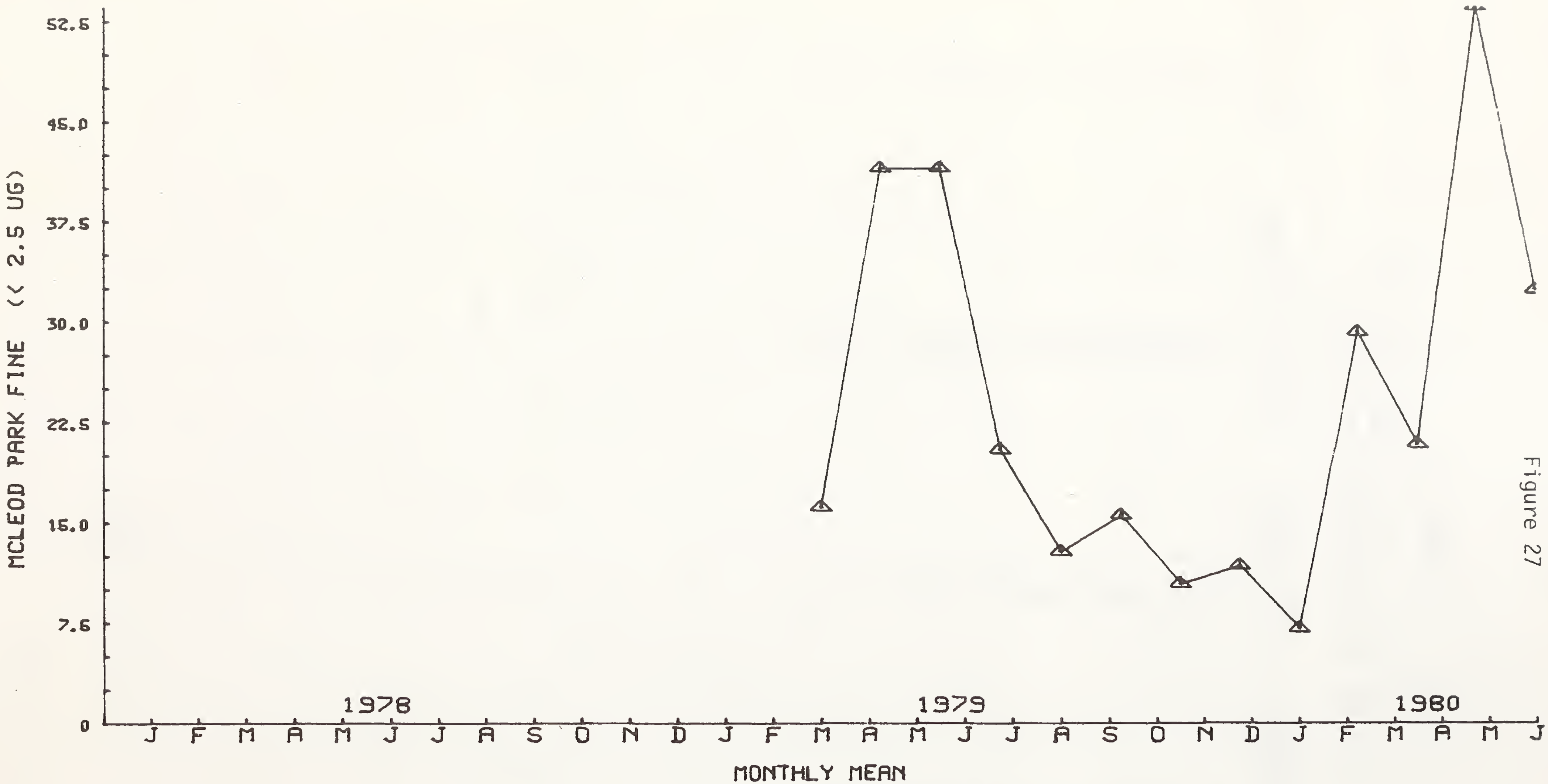
Table 40 and Figures 27 through 29 summarize the monthly average values of the two size ranges, the inhalable particulates and the total suspended particulates as measured by a high-volume sampler at McLeod Park. The particles less than 2.5 microns show the most variation, as average values vary from 7 ug/m$^3$ in August 1979 to 53 ug/m$^3$ in November 1979. The average concentration of particles less than 2.5 microns is 24 ug/m$^3$. The trend of particles less than 2.5 microns as shown in Figure 27 and Table 40 shows highest values in late autumn and early winter and lowest values in the summer. The monthly average concentration of particles in the 2.5 to 15 micron size varied from 5 ug/m$^3$ in December 1978 to 53 ug/m$^3$ in March 1979. However, other than the two extreme values, the monthly averages vary little from month to month. The average concentration of particles from 2.5 to 15 microns was 29 ug/m$^3$. Due to the small variation of concentrations from month to month, no seasonal trend was evident. The particles less than 2.5 microns contributed 45 percent of the total concentration of particles less than 15 microns. Similarly, the particles from 2.5 to 15 microns contributed the remaining 55 percent of the concentration. The contribution percentage of the fine fraction (particles less than 2.5 microns)

TABLE 40

MCLEOD PARK MONTHLY AVERAGE PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Suspended Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Dec 78 | -- | 16 | 5 | 22 |
| Jan 79 | -- | 41 | 23 | 64 |
| Feb | 93 | 41 | 33 | 74 |
| Mar | 157 | 20 | 53 | 73 |
| Apr | 79 | 13 | 24 | 36 |
| May | -- | 15 | 34 | 49 |
| June | -- | 10 | 39 | 49 |
| July | -- | 12 | 34 | 46 |
| Aug | -- | 7 | 19 | 26 |
| Sept | 175 | 29 | 29 | 58 |
| Oct | 101 | 21 | 43 | 64 |
| Nov | 135 | 53 | 10 | 64 |
| Dec | 108 | 32 | 18 | 51 |
| Avg. | 121 | 24 | 29 | 53 |

Figure 27

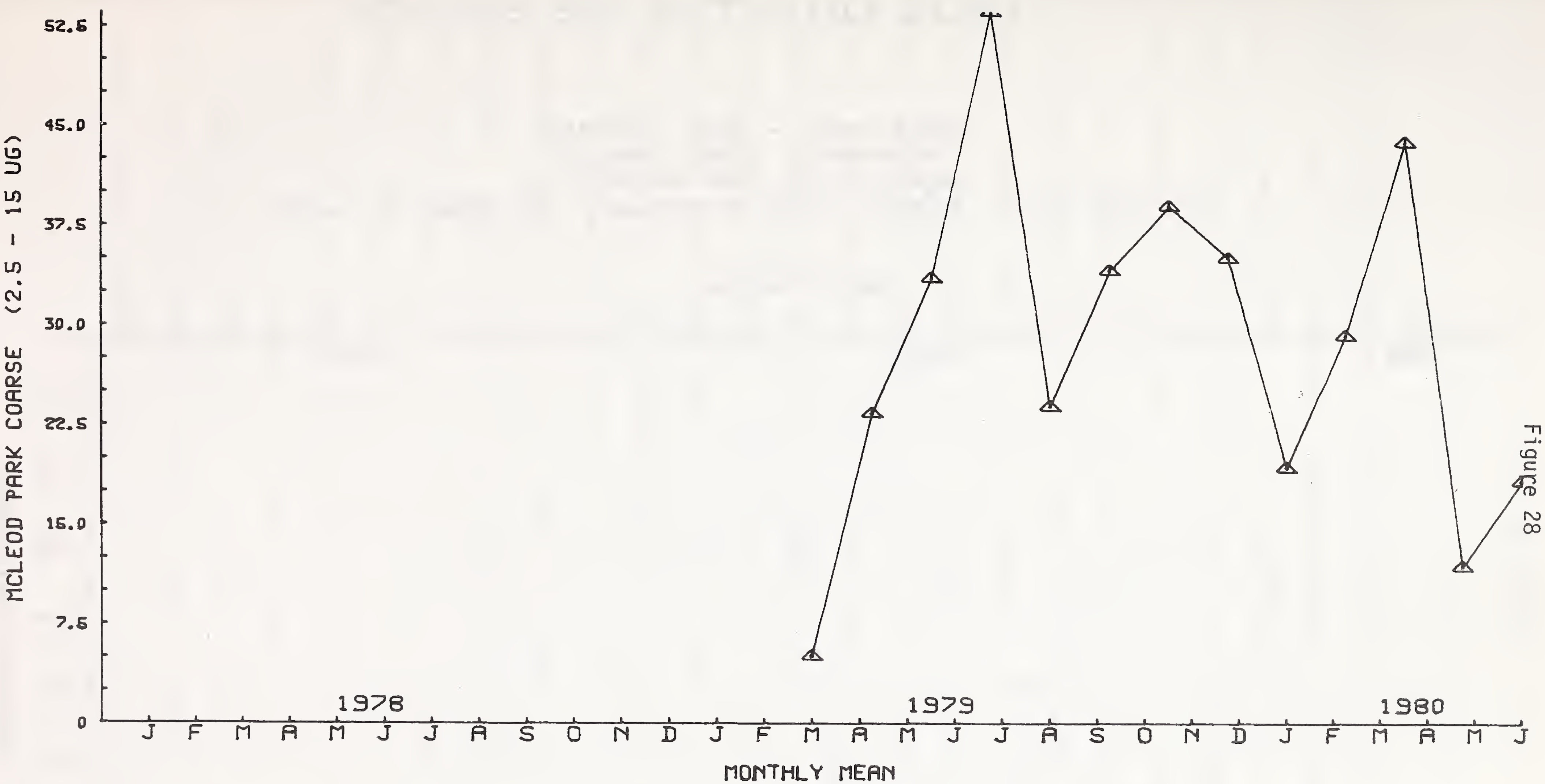



Monthly Mean vs. Fine Particulate (<2.5 ug/m*3)
Micrograms per Cubic Meter
McLeod Park Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 28

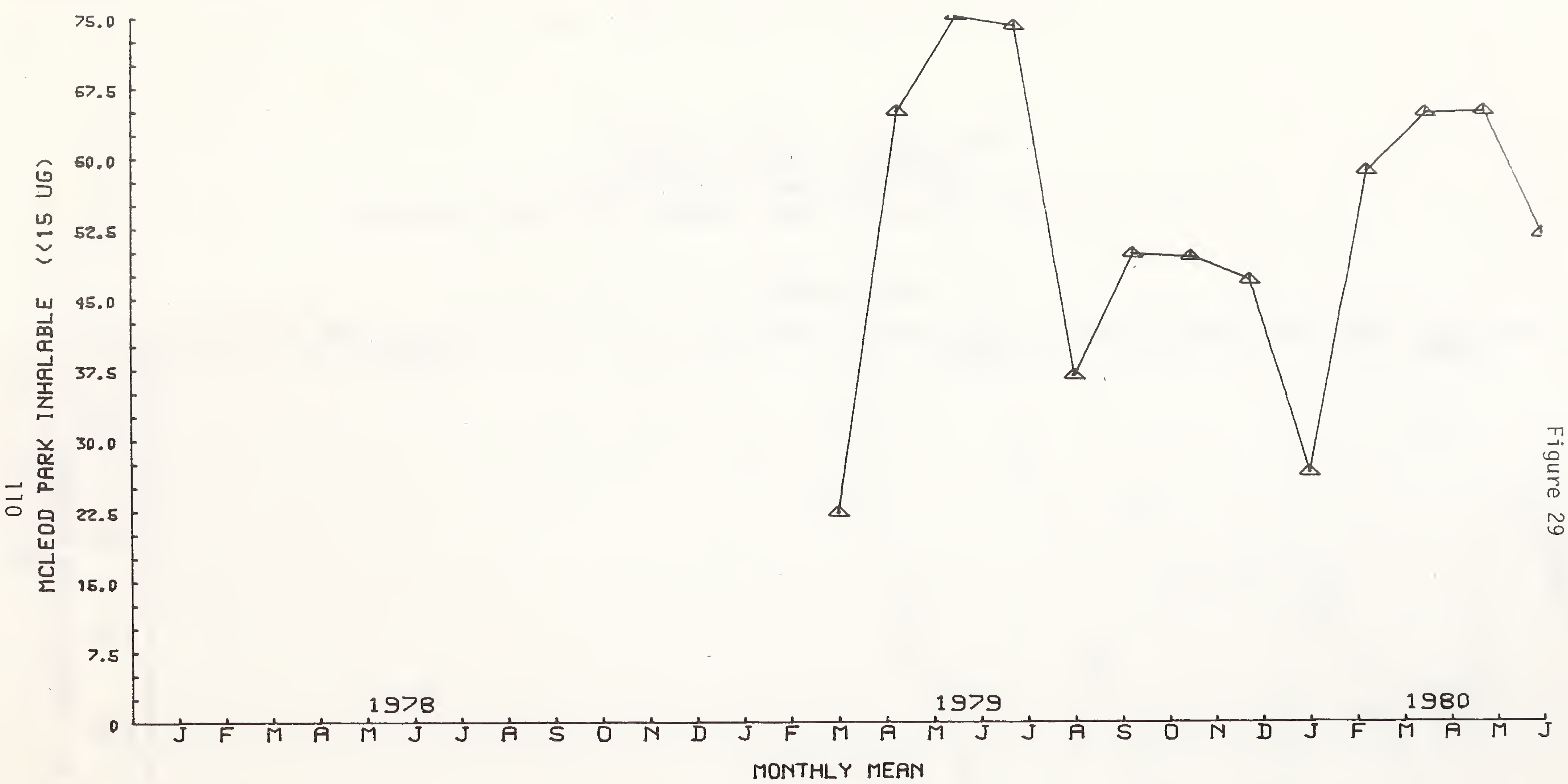



Monthly Mean vs. Coarse Particulate (2.5-15 ug/m*3)
Micrograms per Cubic Meter
McLeod Park Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 29




Monthly Mean vs. Inhalable Particulate (<15 ug/m*3)
Micrograms per Cubic Meter
McLeod Park Missoula
January 1978 - June 1980

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JANUARY 19, 1981

to the inhalable concentration varied from month to month, but on the average, the fine fraction contributed a greater portion of the total inhalable concentration during the winter than the summer. The reverse was true of the coarse fraction, which contributed a greater contribution to the total inhalable concentration during the summer and a lesser contribution during the winter.

At the Courthouse site, summarized in Table 41 and Figures 30 through 32, the concentration of particles less than 2.5 microns again varied more than the coarse fraction. The fine fraction concentration varied from 9 ug/m$^3$ in June 1979 to 47 ug/m$^3$ in January 1979. The average concentration of particles less than 2.5 microns was 19 ug/m$^3$. The trend of the fine fraction concentration was similar at the Courthouse to that at McLeod Park, with highest average concentrations occurring in the late autumn and winter and lowest averages occurring during the summer. The monthly average concentration of particles in the 2.5 to 15 micron size range varied from 12 ug/m$^3$ in January 1979 to 47 ug/m$^3$ in April 1980. The average concentration during the sampling period was 26 ug/m$^3$. The seasonal trend of the coarse fraction had lowest average concentrations in the late autumn and winter and highest average concentrations in the summer. On the average, the fine fraction contributed 43 percent of inhalable particulates, whereas the coarse fraction contributed 57 percent. The percentage of fine fraction contribution to the inhalable concentration was greatest during the winter, when as high as 80 percent came from the fine fraction. During the summer, the figure dropped to as low as 25 percent.

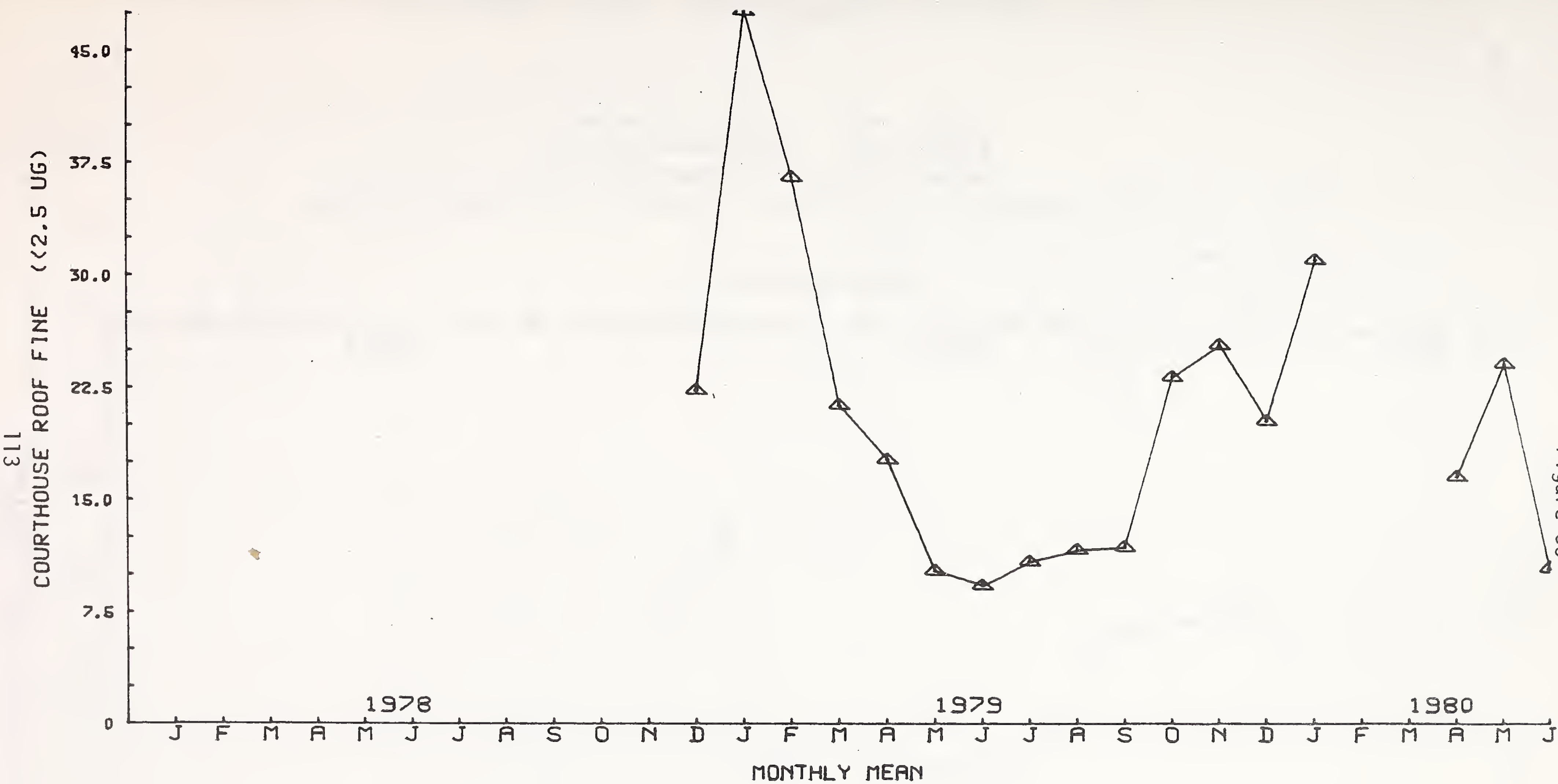
A comparison of the Courthouse fine particulate data to those of McLeod Park shows very little difference in seasonal trends. However, the McLeod Park data revealed not only a higher concentration of the fine fraction of the inhalable

TABLE 41

COURTHOUSE ROOF MONTHLY AVERAGE PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Suspended Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part 15 microns |
|---|---|---|---|---|
| Dec 78 | 68 | 22 | 16 | 36 |
| Jan 79 | 122 | 47 | 12 | 59 |
| Feb | 86 | 36 | 26 | 62 |
| Mar | 116 | 21 | 42 | 63 |
| Apr | 72 | 17 | 26 | 44 |
| May | 77 | 10 | 26 | 36 |
| Jun | 90 | 9 | 26 | 35 |
| Jul | 78 | 11 | 26 | 36 |
| Aug | 79 | 12 | 24 | 35 |
| Sept | 82 | 12 | 18 | 29 |
| Oct | 81 | 23 | 18 | 40 |
| Nov | 118 | 25 | 17 | 42 |
| Dec | 94 | 20 | 16 | 37 |
| Jan 80 | 96 | 31 | 18 | 49 |
| Feb | 145 | -- | -- | -- |
| Mar | 89 | -- | -- | -- |
| Apr | -- | 16 | 42 | 63 |
| May | 72 | 24 | 38 | 60 |
| Jun | -- | 10 | 26 | 36 |
| Average | 92 | 19 | 26 | 44 |
| Average (Dec 78 - Dec 79) | 90 | 18 | 24 | 41 |

Figure 30

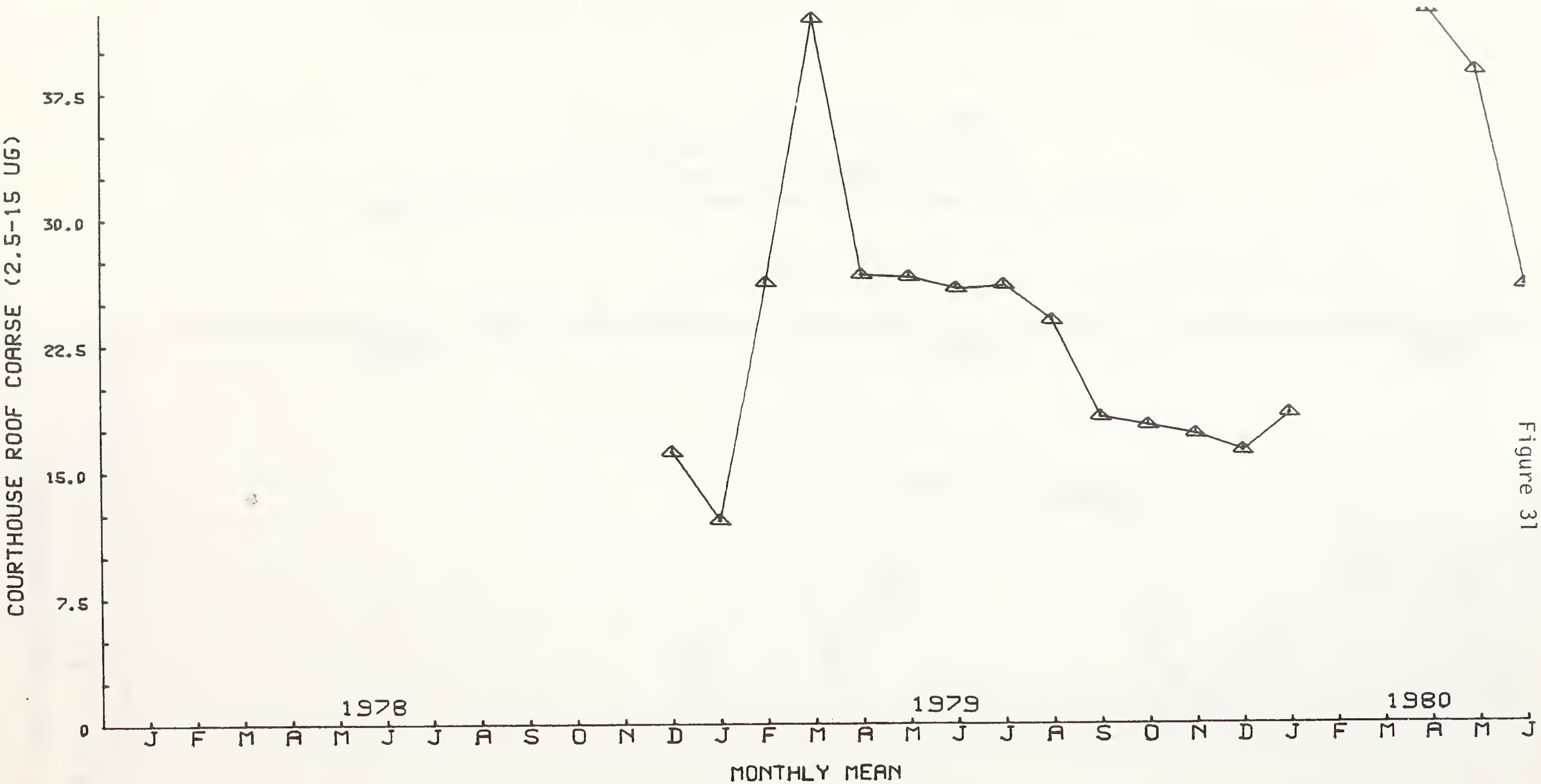



Monthly Mean vs. Fine Particulate (<2.5 ug/m*3)
Micrograms per Cubic Meter
Courthouse Roof Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 31

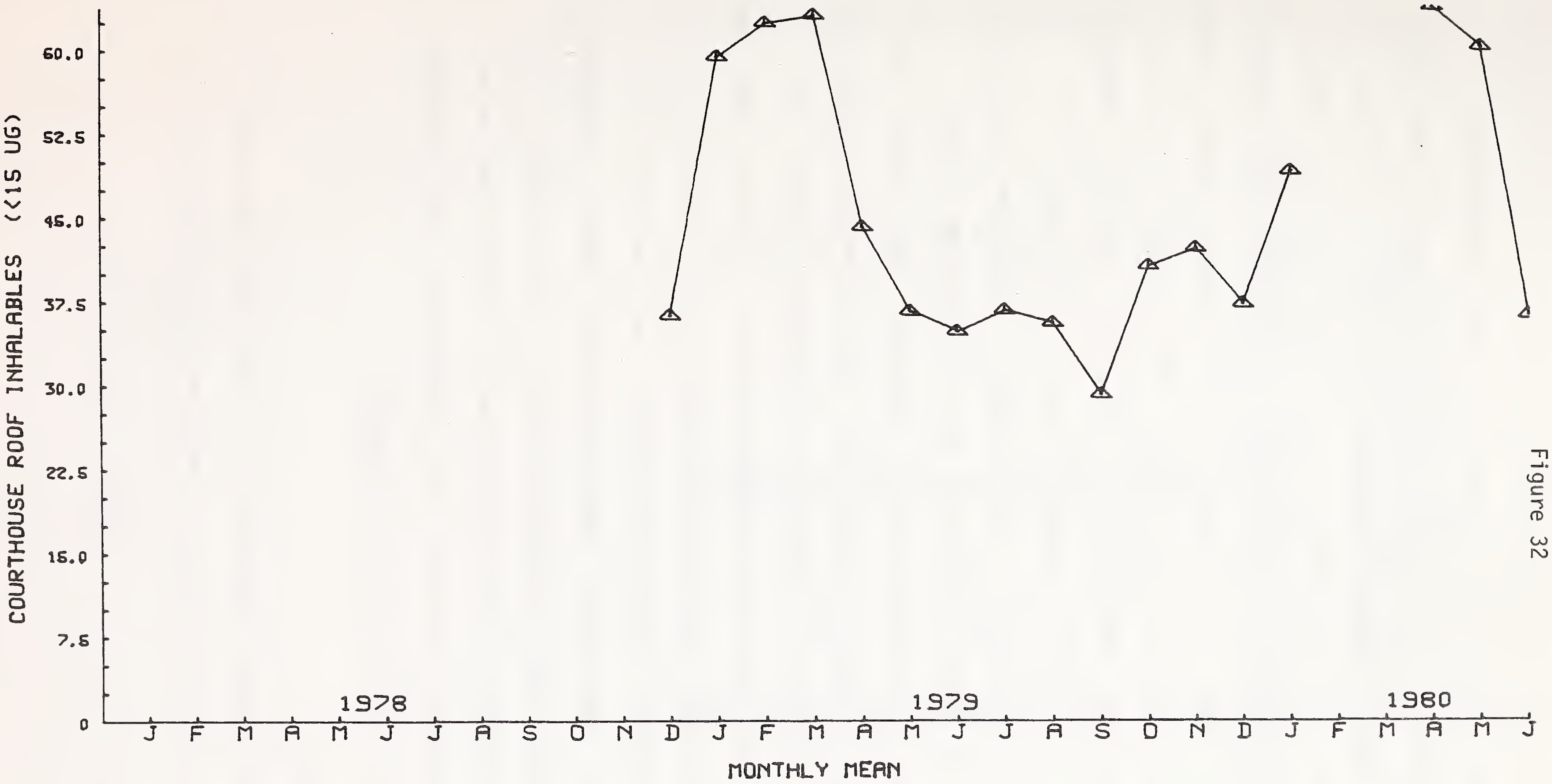



Monthly Mean vs. Coarse Particulate (2.5-15 ug.m•3)
Micrograms per Cubic Meter
Courthouse Roof Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 32




Monthly Mean vs. Inhalable Particulate (<15 ug/m*3)
Micrograms per Cubic Meter
Courthouse Roof Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

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particulates, but also higher total suspended particulate concentrations. However, the concentration of the coarse fraction was the same at both sites.

Table 42 and Figures 33 through 35 summarize the inhalable particulates at the Lions' Park site. The concentration of particulates less than 2.5 microns varied from 10 $ug/m^3$ in April 1979 to 60 $ug/m^3$ in January 1980. The average concentration was 26 $ug/m^3$, and the trend of the fine fraction revealed, as in the case of the previous sites discussed, higher concentrations in the late autumn and winter and lower concentrations in the summer. Particles from 2.5 to 15 microns varied from 2 $ug/m^3$ in January 1979 to 79 $ug/m^3$ in March 1979. The average concentration was 36 $ug/m^3$. Similar seasonal trends were revealed as at the previous sites with highest averages in the late spring and summer. Contributions of the fine fraction and coarse fraction to the inhalable concentration were 42 and 58 percent, respectively. The fine fraction varied from a contribution of 78 percent in December 1978 to 23 percent in April 1979.

Comparing the Lions' Park data to the McLeod Park and Courthouse data, the Lions' Park site had higher concentrations of both the fine fraction and the coarse fraction of the fine particulates. However, the Lions' Park total suspended particulate data revealed lower concentrations than those found at McLeod Park and slightly higher concentrations than at the Courthouse. The Lions' Park area, therefore, recorded higher fine particulates than the two other areas sampled, whereas the other sites recorded more large particulates (particulates greater than 15 microns in diameter).

3. Trace Elements

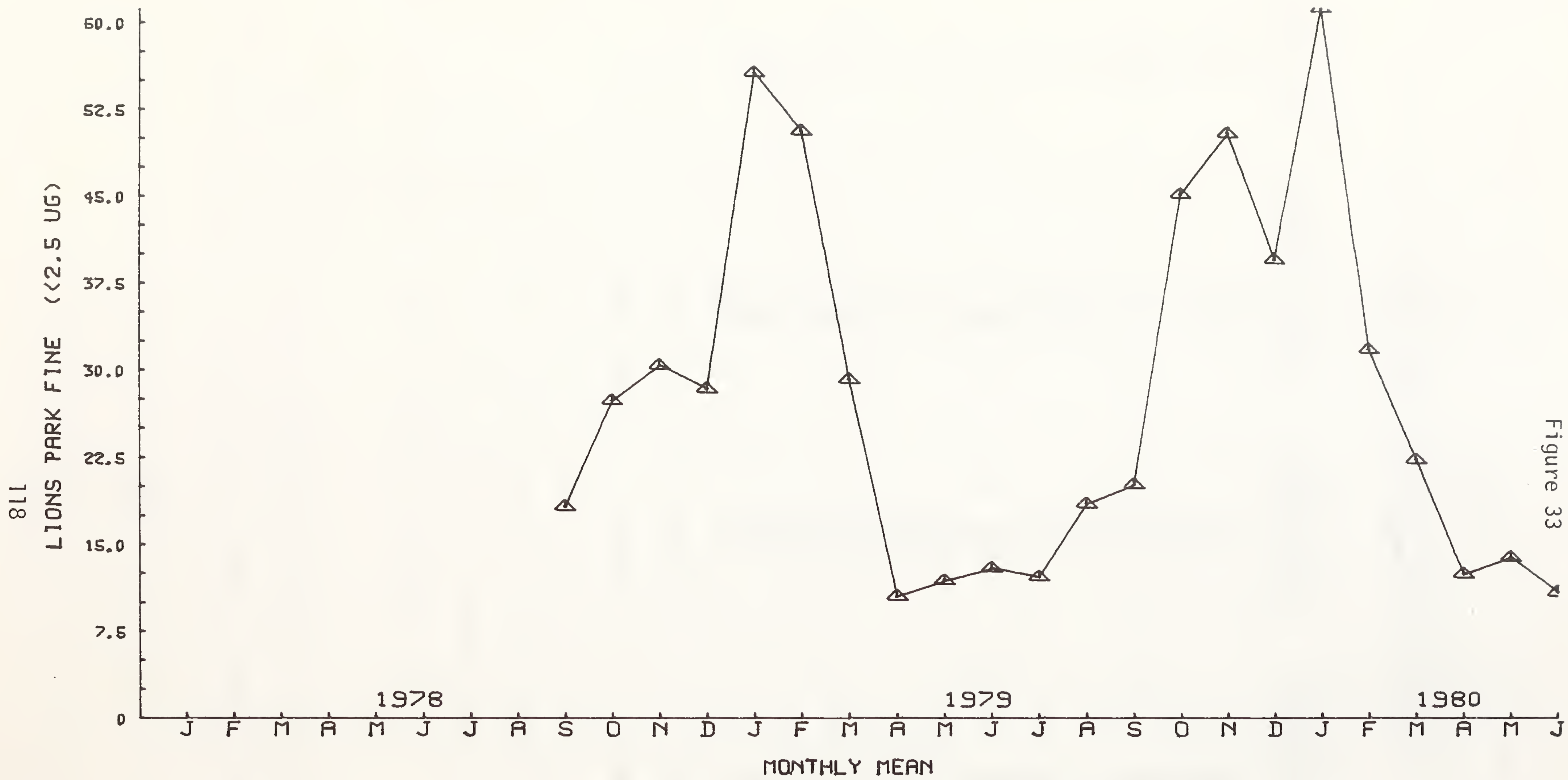
Chemical analyses were performed during MAPS on the high-volume air samples for a variety of trace elements by means of atomic absorption. The

TABLE 42

LIONS' PARK MONTHLY AVERAGE PARTICULATE DATA
(Values in micrograms per cubic meter)

| Month | Total Suspended Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Sep 78 | 70 | 18 | 32 | 49 |
| Oct | 118 | 27 | 42 | 69 |
| Nov | 93 | 30 | 21 | 50 |
| Dec | 71 | 28 | 8 | 36 |
| Jan 79 | 108 | 55 | 2 | 131 |
| Feb | 104 | 50 | 39 | 89 |
| Mar | 170 | 29 | 79 | 108 |
| Apr | 83 | 10 | 33 | 43 |
| Jun | 72 | 13 | 38 | 51 |
| Jul | 74 | 12 | 32 | 44 |
| Aug | 69 | 18 | 26 | 45 |
| Sep | 94 | 20 | 29 | 46 |
| Oct | 96 | 45 | 24 | 68 |
| Nov | 125 | 50 | 26 | 76 |
| Dec | 130 | 39 | 33 | 72 |
| Jan 80 | 135 | 61 | 34 | 94 |
| Feb | 202 | 31 | 48 | 80 |
| Mar | 105 | 22 | 59 | 83 |
| Apr | -- | 12 | 38 | 46 |
| May | 68 | 14 | 46 | 60 |
| Jun | -- | 11 | 32 | 43 |
| Average | 104 | 26 | 36 | 62 |
| Average (Dec 78-Dec 79) | 98 | 27 | 33 | 61 |

Figure 33

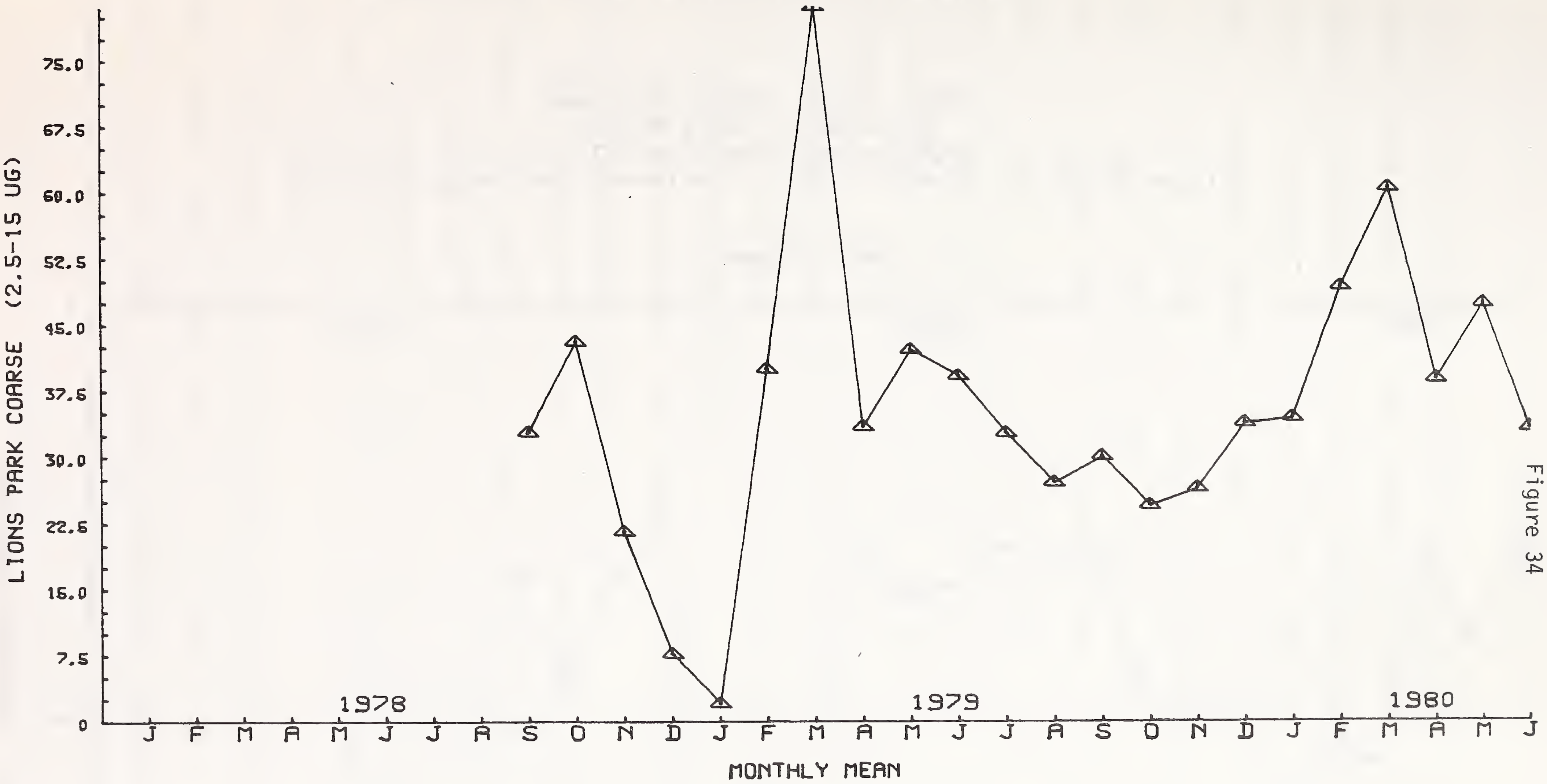



Monthly Mean vs. Fine Particulate (<2.5 ug/m*3)
Micrograms per Cubic Meter
Lions Park Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 34

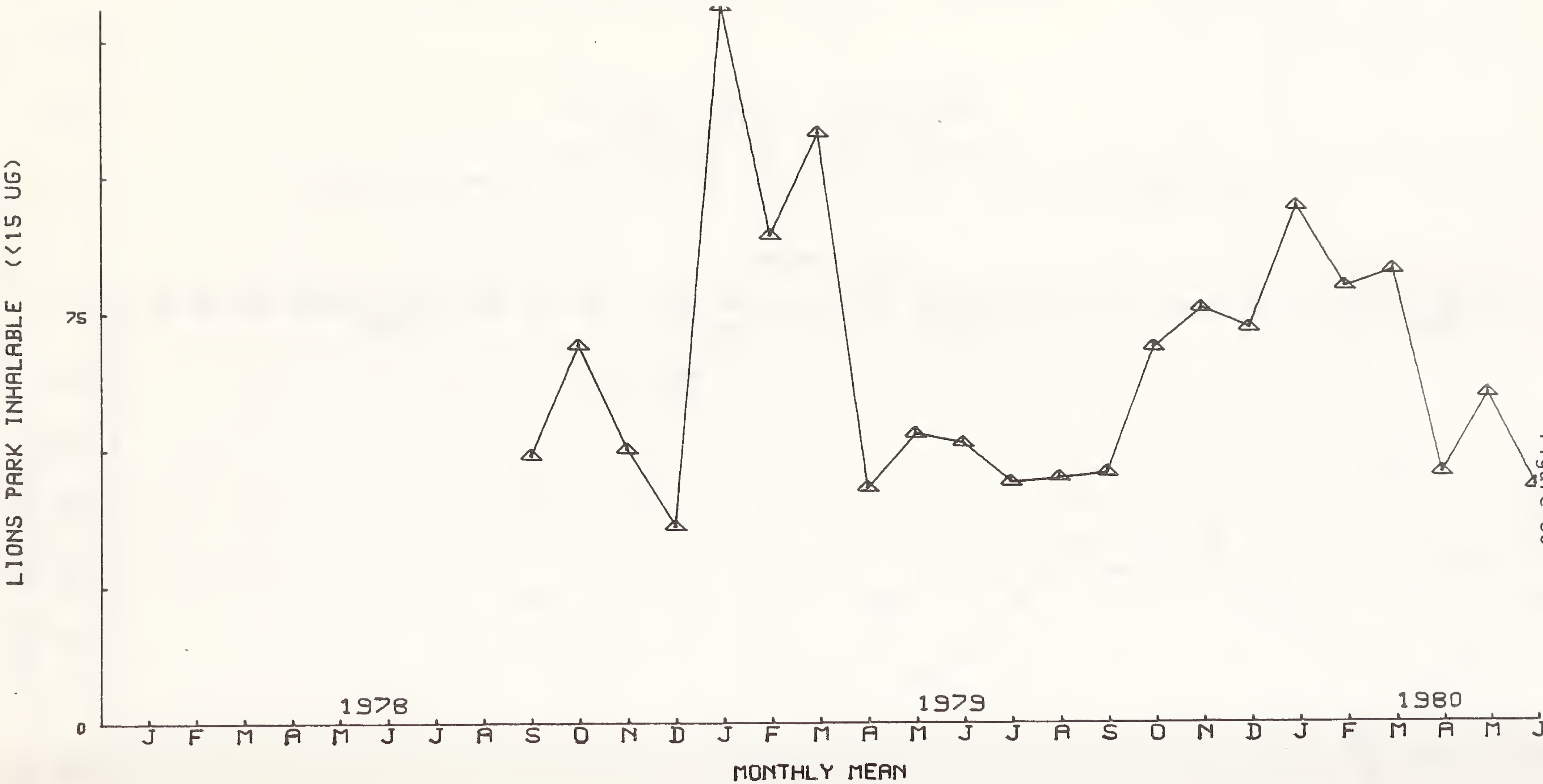



Monthly Mean vs. Coarse Particulate (2.5-15 ug/m*3)
Micrograms per Cubic Meter
Lions Park Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

Figure 35




Monthly Mean vs. Inhalable Particulate (<15 ug/m•3)
Micrograms per Cubic Meter
Lions Park Missoula
January 1978 - June 1980

MONTANA AIR POLLUTION STUDY

JANUARY 19, 1981

results of these analyses are presented in Table 43 for the Courthouse and Tables 44 and 45 for Lions' Park, respectively. Shown in the tables are monthly average concentrations of trace elements and the corresponding average concentrations of total suspended particulates. Table values shown as zero are actually concentrations below the detection limit of the analysis method.

In Table 43, arsenic values ranged from 0.000 $ug/m^3$ during July and August 1979 to 0.012 $ug/m^3$ in November 1978. Comparing arsenic concentrations to those of total suspended particulates, November 1978 had a high average particulate level (111 $ug/m^3$), although it was not the highest. However, July and August 1979 did have fairly low comparative particulate levels. Concentrations of arsenic tended to be highest in the late fall and winter and lowest in the summer.

Concentrations of cadmium varied from 0.000 $ug/m^3$ during January through April 1980 to 0.007 $ug/m^3$ in April 1979. No clear seasonal trend, as with arsenic, was evident with cadmium.

Chromium concentrations were near zero for all months except August 1979. During that month the average was 0.007 $ug/m^3$.

Copper averages reversed the trend described by the arsenic. Copper revealed higher concentrations in summer and lower concentrations in winter. Copper averaged from 0.05 $ug/m^3$ in April 1980 to 0.83 $ug/m^3$ in June 1979.

Iron averages were available for too short a period to provide a clear description of a trend. Iron varied from 0.24 $ug/m^3$ in December 1978 to 3.32 $ug/m^3$ in March 1978.

Lead concentrations, on the other hand, were available for a two and one-half year period. Lead averages varied from 0.08 $ug/m^3$ in April 1980 to 0.62 $ug/m^3$ in November 1978. The trend for lead showed highest concentrations in late autumn and winter and lowest concentrations in late spring and summer.

TABLE 43

COURTHOUSE ROOF MONTHLY AVERAGE TRACE ELEMENT AND PARTICULATE DATA*
(Values in micrograms per cubic meter)

| Month | TSP | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc | Nitrate | Sulfate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 78 | 94 | --- | --- | --- | | --- | --- | --- | --- | | | --- | --- | 13.9 |
| Feb | 119 | --- | --- | --- | | --- | --- | --- | --- | | | --- | --- | 10.1 |
| Mar | 156 | 1.78 | 0.005 | 0.002 | | 0.19 | 3.32 | 0.82 | --- | | | 0.13 | 3.3 | 5.3 |
| Apr | 72 | 0.75 | 0.002 | 0.002 | | 0.14 | 1.11 | 0.29 | --- | | | 0.05 | 1.4 | 3.5 |
| May | 64 | --- | --- | --- | | --- | --- | --- | --- | | | --- | --- | --- |
| Jun | 82 | 0.88 | 0.001 | --- | | 0.30 | 0.99 | 0.23 | 0.04 | | | 0.06 | ---- | --- |
| Jul | 73 | 0.63 | 0.001 | 0.002 | | 0.41 | 0.84 | 0.29 | 0.04 | | | 0.06 | 1.8 | 3.7 |
| Aug | 89 | 0.62 | 0.001 | 0.004 | | 0.32 | 0.89 | 0.33 | 0.05 | | | 0.06 | 1.9 | 4.4 |
| Sept | 83 | 0.79 | 0.002 | 0.002 | | 0.29 | 0.90 | 0.29 | 0.04 | | | 0.07 | 1.6 | 5.1 |
| Oct | 132 | 1.52 | 0.003 | 0.002 | | 0.27 | 1.67 | 0.53 | 0.08 | | | 0.18 | 2.8 | 6.2 |
| Nov | 111 | 0.57 | 0.012 | 0.002 | | 0.22 | 0.70 | 0.62 | 0.05 | | | 0.13 | 4.3 | 6.8 |
| Dec | 68 | 0.11 | 0.004 | 0.002 | | 0.20 | 0.24 | 0.45 | 0.004 | | | 0.09 | 3.9 | 6.3 |
| Jan 79 | 122 | | --- | --- | --- | --- | | --- | --- | --- | --- | | 7.3 | 8.4 |
| Feb | 86 | | 0.004 | 0.004 | --- | 0.12 | | 0.42 | 0.05 | --- | --- | | 5.7 | 5.6 |
| Mar | 116 | | 0.002 | 0.004 | --- | 0.12 | | 0.39 | 0.06 | --- | --- | | 3.6 | 3.4 |
| Apr | 72 | | 0.001 | 0.007 | --- | 0.12 | | 0.18 | 0.05 | 0.030 | --- | | 1.4 | 1.6 |
| May | 77 | | 0.002 | 0.004 | --- | 0.18 | | 0.15 | 0.06 | 0.009 | --- | | 1.3 | 2.7 |
| June | 90 | | 0.002 | --- | --- | 0.83 | | 0.21 | 0.05 | --- | --- | | 1.6 | 2.4 |
| July | 78 | | 0.000 | 0.002 | 0.000 | 0.51 | | 0.17 | 0.04 | 0.001 | 0.00 | | 1.3 | 2.3 |
| Aug | 79 | | 0.000 | 0.003 | 0.007 | 0.26 | | 0.23 | 0.03 | 0.000 | 0.00 | | 1.9 | 3.4 |
| Sep | 82 | | 0.003 | 0.002 | --- | 0.21 | | 0.27 | 0.06 | ---- | --- | | 2.1 | 3.8 |
| Oct | 81 | | 0.001 | 0.000 | 0.000 | 0.24 | | 0.24 | 0.03 | 0.000 | 0.00 | | --- | --- |
| Nov | 118 | | 0.005 | 0.005 | --- | 0.27 | | 0.56 | 0.06 | --- | --- | | 4.7 | 5.6 |
| Dec | 94 | | 0.005 | 0.001 | 0.000 | 0.31 | | 0.24 | 0.04 | 0.000 | 0.00 | | --- | --- |
| Jan 80 | 96 | | 0.003 | 0.000 | 0.000 | 0.22 | | 0.25 | 0.03 | 0.000 | 0.00 | | 3.7 | 6.3 |
| Feb | 145 | | 0.006 | 0.000 | 0.000 | 0.07 | | 0.32 | 0.004 | 0.000 | 0.00 | | 6.7 | 6.5 |
| Mar | 89 | | 0.001 | 0.000 | 0.000 | 0.12 | | 0.14 | 0.04 | 0.000 | 0.00 | | 2.0 | 4.0 |
| Apr | --- | | 0.001 | 0.000 | 0.000 | 0.05 | | 0.08 | 0.05 | 0.000 | 0.00 | | 1.5 | 3.7 |
| May | 72 | | --- | --- | --- | --- | | --- | --- | --- | --- | | 1.0 | 4.7 |
| Jun | --- | | --- | --- | --- | --- | | --- | --- | --- | --- | | 0.6 | 4.7 |

*Collection method - high volume air sampler (glass fiber filter) and atomic absorption analysis
Values presented as zero are actually less than detection limit of the analysis method.

TABLE 44

LIONS' PARK MONTHLY AVERAGE TRACE ELEMENT AND PARTICULATE DATA*
(Values in micrograms per cubic meter)

| Month | TSP | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc | Nitrate | Sulfate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 78 | 116 | --- | --- | --- | | --- | --- | --- | --- | --- | | --- | --- | 14.4 |
| Feb | 169 | 2.41 | 0.020 | 0.003 | | 0.07 | 3.75 | 1.20 | 0.10 | --- | | 0.19 | --- | 6.8 |
| Mar | 226 | 2.03 | 0.004 | 0.002 | | 0.19 | 2.58 | 0.69 | 0.07 | --- | | 0.11 | 3.5 | 4.2 |
| Apr | 76 | 0.71 | 0.001 | 0.001 | | 0.18 | 1.05 | 0.33 | 0.03 | --- | | 0.08 | 1.5 | 3.0 |
| May | 61 | --- | --- | --- | | --- | --- | --- | --- | --- | | 0.04 | 1.5 | 2.2 |
| Jun | 76 | 0.76 | --- | 0.003 | | 0.17 | 0.78 | 0.30 | 0.05 | 0.007 | | 0.04 | 1.5 | 2.4 |
| Jul | 65 | 0.55 | 0.001 | --- | | 0.20 | 0.76 | 0.28 | 0.02 | 0.005 | | 0.05 | 1.7 | 3.1 |
| Aug | 69 | 0.93 | --- | 0.005 | | 0.05 | 1.31 | 0.36 | 0.02 | --- | | --- | 1.6 | 3.7 |
| Sep | 70 | --- | --- | --- | | --- | --- | --- | --- | --- | | --- | 2.9 | 3.6 |
| Oct | 118 | 0.55 | --- | 0.001 | | 0.02 | 0.44 | 0.41 | --- | --- | | 0.06 | 4.4 | 5.4 |
| Nov | 93 | 0.53 | 0.020 | 0.002 | | 0.08 | 0.35 | 0.52 | 0.03 | 0.009 | | 0.05 | 4.3 | 5.0 |
| Dec | 71 | 0.16 | 0.018 | 0.002 | | 0.07 | 0.17 | 0.56 | 0.03 | 0.005 | | 0.5 | 4.3 | 5.0 |
| Jan 79 | 108 | 0.08 | 0.005 | 0.003 | --- | 0.06 | 0.11 | 0.70 | 0.04 | --- | --- | 0.08 | 7.4 | 7.6 |
| Feb | 104 | | 0.008 | 0.008 | ---- | 0.19 | | 0.57 | 0.04 | 0.010 | --- | | 6.3 | 4.4 |
| Mar | 170 | | 0.002 | 0.005 | 0.014 | 0.10 | | 0.43 | 0.06 | 0.006 | --- | | 4.3 | 3.3 |
| Apr | 83 | | 0.001 | 0.004 | --- | 0.14 | | 0.21 | 0.05 | 0.040 | ---- | | 1.6 | 2.6 |
| May | 75 | | 0.001 | 0.004 | --- | 0.20 | | 0.19 | 0.05 | 0.015 | ---- | | 1.6 | 2.3 |
| Jun | 72 | | 0.001 | 0.001 | 0.021 | 0.22 | | 0.19 | 0.04 | --- | --- | | 1.6 | 1.9 |
| Jul | 74 | | 0.000 | 0.002 | 0.002 | 0.12 | | 0.18 | 0.03 | 0.001 | 0.00 | | 1.4 | 2.0 |
| Aug | 69 | | 0.000 | 0.003 | 0.001 | 0.20 | | 0.29 | 0.04 | 0.003 | 0.00 | | 2.0 | 2.9 |
| Sep | 94 | | 0.004 | 0.003 | --- | 0.13 | | 0.34 | 0.05 | --- | --- | | 2.5 | 3.2 |
| Oct | 96 | | 0.000 | 0.000 | 0.000 | 0.17 | | 0.31 | 0.02 | 0.000 | 0.00 | | --- | --- |
| Nov | 125 | | 0.006 | 0.003 | --- | 0.18 | | 0.65 | 0.03 | --- | --- | | 5.0 | 5.9 |
| Dec | 130 | | 0.001 | 0.001 | 0.000 | 0.24 | | 0.84 | 0.02 | 0.000 | 0.00 | | --- | --- |
| Jan 80 | 135 | | 0.003 | 0.001 | 0.000 | 0.08 | | 0.25 | 0.02 | 0.000 | 0.00 | | 3.2 | 5.2 |
| Feb | 202 | | 0.005 | 0.000 | 0.000 | 0.14 | | 0.31 | 0.03 | 0.000 | 0.00 | | 5.9 | 7.4 |
| Mar | 105 | | 0.002 | 0.000 | 0.000 | 0.16 | | 0.09 | 0.03 | 0.000 | 0.00 | | 2.0 | 3.1 |
| Apr | --- | | 0.001 | 0.000 | 0.000 | 0.27 | | 0.12 | 0.04 | 0.000 | 0.00 | | 1.5 | 3.2 |
| May | 68 | | --- | --- | --- | --- | | --- | --- | --- | ---- | | 0.7 | 4.2 |
| Jun | --- | | --- | --- | --- | --- | | --- | --- | --- | --- | | 0.5 | 3.8 |

*Collection method - high volume air sampler (glass fiber filter) and atomic absorption anaysis. Values presented as zero are actually less than detection limit of the analysis method.

TABLE 45

LIONS' PARK MONTHLY AVERAGE TRACE ELEMENT DATA*
(Values in micrograms per cubic meter)

| Month | Aluminum | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Manganese | Nickel | Vanadium | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov 78 | 0.68 | 0.013 | 0.006 | 0.03 | --- | 0.72 | 0.79 | 0.04 | --- | --- | 0.10 |
| Dec | 0.18 | 0.009 | 0.005 | 0.03 | --- | 0.23 | 0.56 | 0.02 | --- | --- | 0.08 |
| Jan 79 | 0.07 | 0.009 | 0.004 | | 0.04 | 0.22 | 0.67 | 0.03 | --- | --- | 0.17 |
| Feb | 0.38 | 0.010 | 0.006 | | 0.04 | 0.66 | 0.61 | 0.03 | --- | --- | 0.12 |
| Mar | 0.95 | 0.003 | 0.004 | | 0.03 | 1.28 | 0.42 | 0.04 | --- | --- | 0.11 |
| Apr | 0.37 | 0.002 | --- | | 0.02 | 0.57 | 0.23 | 0.02 | --- | --- | 0.05 |
| May | 0.79 | 0.001 | --- | | --- | 0.82 | 0.23 | 0.04 | 0.036 | --- | 0.08 |
| Jun | 0.56 | 0.001 | --- | | 0.11 | 0.59 | 0.25 | --- | 0.043 | 0.07 | 0.06 |
| Jul | 0.67 | 0.001 | 0.041 | | 0.14 | 0.69 | 0.28 | --- | 0.509 | 0.07 | 0.12 |
| Aug | 0.84 | 0.001 | 0.010 | | 0.13 | 0.91 | 0.33 | 0.04 | --- | 0.08 | 0.05 |
| Sep | 1.06 | 0.001 | --- | | --- | 1.77 | 0.44 | 0.06 | 0.030 | 0.07 | 0.06 |
| Oct | 1.60 | 0.001 | --- | | --- | 1.45 | 0.66 | 0.07 | --- | 0.05 | 0.08 |
| Nov | --- | --- | --- | | --- | --- | --- | --- | --- | --- | --- |
| Dec | 0.32 | 0.000 | 0.000 | | 0.05 | 0.38 | 0.32 | 0.02 | 0.000 | 0.00 | 0.04 |
| Jan 80 | --- | --- | --- | --- | -- | -- | --- | --- | --- | --- | --- |
| Feb | 2.96 | 0.001 | 0.000 | 0.000 | 0.11 | 2.62 | 0.61 | 0.08 | 0.000 | 0.00 | 0.07 |
| Mar | 1.63 | 0.000 | 0.000 | 0.000 | 0.08 | 1.45 | 0.24 | 0.05 | 0.000 | 0.00 | 0.05 |
| Apr | 0.97 | 0.000 | 0.000 | 0.000 | 0.06 | 1.01 | 0.18 | 0.05 | 0.000 | 0.00 | 0.03 |

*Collection method - membrane air sampler (fluorocarbon-base filter) and atomic absoprtion analysis

Manganese averages showed very little variation from month to month, as averages varied from 0.03 ug/$m^3$ in August 1979, October 1979, and January 1980 to 0.08 ug/$m^3$ in October 1978. Nickel, vanadium, and zinc sampling periods were used to establish a trend. Most of the nickel and vanadium averages were below the detection limit. Zinc averages varied from 0.05 ug/$m^3$ in April 1978 to 0.18 ug/$m^3$ in October 1978.

Nitrate averages showed a seasonal trend similar to other data presented. Highest averages occurred during the late autumn and winter, while lowest averages occurred during the summer. Averages varied from 0.6 ug/$m^3$ in June 1980 to 7.3 ug/$m^3$ in January 1979.

Sulfate averages did not show the same amount of month-to-month variation as the nitrate values. Averages varied from 1.6 ug/$m^3$ in April 1979 to 13.9 ug/$m^3$ in January 1978. However, the monthly averages varied very little and averaged about 4 ug/$m^3$.

Table 44 summarizes the monthly average trace element data obtained from the high-volume air samples at Lions' Park. Aluminum data were available only during 1978 and early 1979. Averages varied from 0.08 ug/$m^3$ in January 1979 to 2.41 ug/$m^3$ in February 1978. No seasonal or overall trend was evident from the available data.

Arsenic data were available for about two years at Lions' Park. Averages varied from 0.000 ug/$m^3$ (below detection limit) to 0.020 ug/$m^3$. Highest averages occurred during the winter, while lowest averages occurred during the summer. During most months the arsenic levels at Lions' Park were about the same as those measured at the Courthouse station. The highest averages measured at Lions' Park were higher than those recorded at the Courthouse.

Cadmium levels at Lions' Park ranged from below the detection level to 0.008 ug/m$^3$ in February 1979. No seasonal trend was apparent. Values at the Lions' Park station were very similar to those measured at the Courthouse site.

Copper values were lower at the Lions' Park site than at the Courthouse. Lions' Park averages varied from 0.02 ug/m$^3$ in October 1978 to 0.27 ug/m$^3$ in April 1980. During 1978 and 1979 Courthouse copper averages were from 1.5 to 10 times as high as the Lions' Park averages. During 1980 the averages were more nearly equal at both sites.

Most of the remainder of trace elements were similar at both the Lions' Park and Courthouse sites. At the Lions' Park site, lead averages ranged from 0.09 ug/m$^3$ in March 1980 to 1.20 ug/m$^3$ in February 1978. Manganese ranged from 0.02 ug/m$^3$ during several months to 0.10 ug/m$^3$ in February 1978.

Nitrate monthly averages at Lions' Park varied from 0.5 ug/m$^3$ in June 1980 to 7.4 ug/m$^3$ in January 1979. Seasonal trends indicated highest averages during the late autumn and early winter, with lowest averages during the summer. Values at the Lions' Park site were similar to those at the Courthouse site.

Sulfate monthly averages at Lions' Park varied from 1.9 ug/m$^3$ in June 1979 to 14.4 ug/m$^3$ in January 1978. Seasonal trends again indicated higher concentrations during the winter and lower concentrations during the summer. Concentrations were fairly similar from year to year. Concentrations at the Courthouse and Lions' Park sites also were similar.

At the Lions' Park site sampling also was performed for trace elements using a membrane sampler and cellulose filters. Analyses were performed on the membrane samples for similar trace elements. The results of those analyses are presented as monthly averages for the membranes and high-volume air samples. Only copper and manganese show any apparent difference with the high-volume samples, as the two elements average higher concentrations than on the membrane.

4. Gaseous Pollutants

Sampling was performed for a variety of gaseous compounds at the Lions' Park site in Missoula. Sampling for carbon monoxide was conducted only at the Malfunction Junction site. The results of the sampling at both sites are presented in Tables 46 through 48.

Table 46 summarizes the carbon monoxide data for the Malfunction Junction and Lions' Park sampling sites. The Malfunction Junction samplers were operated intermittantly from January 1978 through April 1980. The maximum one-hour concentration of carbon monoxide at the Malfunction Junction site was 28.0 parts per million (ppm), which compares to the federal primary ambient standard of 35 ppm (not to be exceeded more than once per year) and the Montana ambient standard of 23 ppm (not to be exceeded more than once per year). Since both the Montana and federal standards allow at least one excursion per year, Table 46 also lists the second highest one-hour carbon monoxide concentration. At the Malfunction Junction site, the second highest one-hour concentration was 27.5 ppm, which occurred within the same year as the highest value. Therefore, the second highest would constitute a violation of the Montana one-hour standard. The highest eight-hour carbon monoxide concentration at the Malfunction Junction site was 21.6 ppm. Similarly, the second-highest concentration at the same site was 19.0 ppm. This second highest value is well above the federal and Montana ambient standard of 9.0 ppm, not to be exceeded more than once per year. The overall average concentration for the sampling period was 5.0 ppm.

At the Lions' Park site, the sampler also was operated intermittantly from January 1978 through April 1980. The maximum one-hour carbon monoxide concentration recorded was 24.3 ppm, while the second highest concentration was 24.0 ppm. However, the second highest concentration occurred during a separate

TABLE 46

MISSOULA AREA CARBON MONOXIDE DATA SUMMARY
(Values in parts per million)

| Averaging Time | Malfunction Jct. (Jan-Jun 78, Jun 79, Dec 79-Apr 80) | Lions Park (Jan-Apr 78, Jan-Jun 79, Nov 79-Apr 80) |
|---|---|---|
| 1-hour maximum (high) | 28.0 | 24.3 |
| 1-hour maximum (2nd high) | 27.5 | 24.0+ |
| 8-hour maximum (high) | 21.6 | 16.2 |
| 8-hour maximum (2nd high) | 19.0 | 15.7 |
| Average* | 5.0 | 2.6 |
| No. of Readings | 6164 | 6815 |

*Time period of average varies by site

+Occurred during separate year. Second highest during same year was 20.5 ppm

TABLE 47

LIONS PARK GASEOUS POLLUTANT DATA SUMMARY
(Values in parts per million)

| Averaging Time | Sulfur Dioxide (Jan-Oct 78) | Nitrogen Dioxide (Jan-Oct 78, Jul-Oct 79) | Carbon Monoxide (Jan-Apr 78, Jan-Jun 79, Nov 79-Apr 80) | Total Hydrocarbons (Jan 78-Feb 79, Jul 79-June 80) | Ozone (Jan 78-Oct 79) |
|---|---|---|---|---|---|
| 1-hour max. | 0.05 | 0.186 | 24.3 | --- | 0.078 |
| 3-hour maximum | 0.04 | --- | --- | 4.13[a] | --- |
| 8-hour maximum | --- | --- | 16.2 | --- | --- |
| 24-hour max.[+] | 0.02 | 0.043 | 10.8 | 3.87 | 0.044 |
| Average | 0.00 | 0.016 | 2.6 | 2.17 | 0.016 |
| No. of Readings | 5781 | 6932 | 6815 | 11,437 | 11,207 |

[+]Midnight to midnight
[a]3-hour aerage from 6 to 9 a.m.

TABLE 48

LIONS PARK MONTHLY AVERAGE AIR QUALITY SUMMARY

| Month | Total Susp. Particulates* | Susp. Part. 2.5 microns* | Susp. Part 2.5 to 15 microns* | Sulfur Dioxide+ | Nitroen Dioxide+ | Ozone+ | Total Hydrocarbons+ | Carbon Monoxide+ | Peta Scatter[a] | Susp. Particulate |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan 78 | 116 | --- | --- | 0.00 | 0.023 | 0.006 | 2.14 | 8.2 | 31 | --- |
| Feb | 169 | --- | --- | 0.00 | 0.027 | 0.012 | 2.16 | --- | 33 | --- |
| Mar | 226 | --- | --- | 0.00 | 0.017 | 0.021 | 2.05 | 1.9 | 20 | --- |
| Apr | 76 | --- | --- | 0.00 | 0.015 | 0.017 | 1.79 | 1.2 | 7 | --- |
| May | 61 | --- | --- | 0.00 | 0.013 | 0.022 | 1.81 | --- | 7 | --- |
| Jun | 76 | --- | --- | 0.00 | 0.010 | 0.023 | 1.87 | --- | 7 | 31 |
| Jul | 65 | --- | --- | 0.00 | 0.011 | 0.023 | 2.05 | --- | 7 | 39 |
| Aug | 69 | --- | --- | 0.00 | 0.012 | 0.022 | 2.12 | --- | 8 | 50 |
| Sep | 70 | 18 | 32 | 0.00 | 0.014 | 0.016 | 2.34 | --- | 9 | 40 |
| Oct | 118 | 27 | 42 | 0.00 | 0.021 | 0.015 | 2.33 | --- | 18 | 79 |
| Nov | 93 | 30 | 21 | --- | --- | 0.010 | 2.31 | --- | 39 | 78 |
| Dec | 71 | 28 | 8 | --- | --- | 0.008 | --- | --- | 31 | 57 |
| Jan 79 | 108 | 55 | 2 | | --- | 0.004 | 2.74 | 5.6 | 61 | 93 |
| Feb | 104 | 50 | 39 | | --- | 0.010 | 2.61 | 3.6 | 38 | 86 |
| Mar | 170 | 29 | 79 | | --- | 0.018 | --- | 2.3 | 25 | 117 |
| Apr | 83 | 10 | 33 | | --- | 0.025 | --- | 1.3 | --- | 57 |
| May | 75 | 12 | 41 | | --- | 0.019 | --- | 1.1 | --- | 51 |
| Jun | 72 | 13 | 38 | | --- | --- | --- | 0.8 | --- | 47 |
| Jul | 74 | 12 | 32 | | 0.014 | 0.028 | 1.82 | --- | --- | 52 |
| Aug | 69 | 18 | 26 | | --- | --- | 1.87 | --- | --- | 48 |
| Sep | 94 | 20 | 29 | | 0.021 | 0.013 | 2.10 | --- | 11 | 68 |
| Oct | 96 | 45 | 24 | | 0.026 | 0.009 | 2.20 | --- | 14 | 91 |
| Nov | 125 | 50 | 26 | | --- | --- | --- | 3.4 | --- | --- |
| Dec | 130 | 39 | 33 | | --- | --- | 2.57 | 3.8 | --- | --- |
| Jan 80 | 135 | 60 | 34 | | | | 2.22 | 2.5 | 41 | 36 |
| Feb | 202 | 31 | 48 | | | | 2.39 | 2.7 | 39 | --- |
| Mar | 105 | 22 | 59 | | | | 2.00 | 0.8 | 18 | --- |
| Apr | --- | 12 | 38 | | | | --- | 2.6 | --- | --- |
| May | 68 | 14 | 46 | | | | --- | --- | --- | --- |
| Jun | --- | 11 | 32 | | | | 1.82 | --- | --- | --- |

*Values in micrograms per cubic meter
+Values in parts per million
[a]Values in scattering coefficient per meter x $10^5$
[b]Measured by a beta counter, values in micrograms per cubic meter

year. The second-highest one-hour carbon monoxide concentration during the same year was 20.5 ppm, which falls below the federal and Montana one-hour ambient standard. The highest eight-hour carbon monoxide concentration recorded was 16.2 ppm. Similarly, the second-highest concentration was 15.7 ppm, which exceeds both the federal and Montana eight-hour standards of 9.0 ppm. The average carbon monoxide concentration at the Lions' Park site during the sampling period was 2.6 ppm.

Table 47 summarizes the gaseous pollutants measured during MAPS at the Lions' Park site. Sulfur dioxide was sampled from January through October 1978. The maximum one-hour concentration was 0.05 ppm, which is well below the Montana ambient standard of 0.50 ppm, not to be exceeded more than eighteen times per year. The maximum three-hour concentration of sulfur dioxide was 0.04 ppm, which also is well below the federal secondary standard of 0.50 ppm, not to be exceeded more than once per year. Similarly, the maximum twenty-four hour sulfur dioxide concentration of 0.02 ppm was well below the Montana ambient standard of 0.10 ppm and the federal primary standard of 0.14 ppm.

Nitrogen dioxide levels recorded at the Lions' Park site also were low. Sampling was performed from January 1978 through October 1979, and the maximum one-hour nitrogen dioxide concentration recorded was 0.186 ppm. This concentration is well below the Montana ambient standard of 0.30 ppm, not to be exceeded more than once per year. The twenty-four hour maximum nitrogen dioxide concentration was 0.043 ppm. The average concentration during the sampling period was 0.016 ppm, below the federal and Montana annual ambient standard of 0.05 ppm. The monthly average nitrogen dioxide concentrations in Table 48 reveal a trend toward highest averages during the late autumn and winter and lowest averages during the summer.

Total hydrocarbons were measured at the Lions' Park site from January 1978 through June 1980. The maximum three-hour hydrocarbon concentration measured from 0600 to 0900 at Lions' Park was 4.13 ppm. The federal ambient guideline is 0.24 ppm for the same time period but only for non-methane hydrocarbons. Therefore, a direct comparison with the standard is not possible with these data. The maximum twenty-four hour and overall average concentrations were 3.87 ppm and 2.17 ppm, respectively. The monthly average concentrations shown in Table 48 reveal little significant variation from month to month. A slight tendency toward higher concentrations in the autumn and winter and lower concentrations in the summer exists.

Ozone was measured at the Lions' Park site from January 1978 through October 1979. The maximum one-hour concentration measured was 0.078 ppm, which compares with the federal primary standard of 0.12 ppm and the Montana standard of 0.10 ppm. The maximum twenty-four hour and overall average concentrations of ozone measured at Lions' Park were 0.044 ppm and 0.016 ppm, respectively. In Table 48, monthly average ozone concentrations reveal a tendency toward highest concentrations during the summer and lowest concentrations during the winter. The monthly averges varied from 0.004 ppm in January 1979 to 0.028 ppm in July 1979.

Table 48 also lists the monthly average beta scatter as measured by an integrating nephelometer and suspended particulates as measured by a beta counter. The beta scatter or scattering coefficient is related to the concentration of small particles in the air that obstruct visibility. A scattering coefficient of about 3 is considered very clean air, while values increasing in magnitude indicate more and more particulates in the air, hence, reduced visibility. At the Lions' Park site, sampling using a nephelometer was conducted from January 1978 through March 1979 and then intermittantly from

September 1979 through March 1980. Results listed in Table 48 indicate reduced visibility and increased particulates during the autumn and winter, with poorest visibility during the winter. The best visibility was revealed during the late spring and summer.

The suspended particulates measured by the beta counter reveal a similar pattern to that of the nephelometer, with highest readings taken in the winter and lowest values in the summer. Comparisons of the readings to those measured by the high-volume air sampler also confirm this finding.

## C. SUMMARY AND CONCLUSIONS

MAPS has provided valuable data on air pollution levels found in the Missoula area. Data were collected on concentrations of total suspended particulates, fine particulates, trace elements, and gaseous pollutants. Total suspended particulate concentrations were in excess of the federal and Montana standards at most stations. Monthly average concentrations revealed a trend of highest concentrations during the winter and early spring and lowest concentrations during the summer.

Although no federal or Montana standard has been adopted, fine particulate data were collected at several locations in the Missoula area. Generally the fine fraction of inhalable particulates showed highest values in late autumn and early winter and lowest values in the summer. The average concentration of the fine fraction was 25 $ug/m^3$. The coarse fraction concentration did not have much variation from month to month; hence, no seasonal trend was apparent. The average coarse fraction concentration ranged from 29 to 36 ug/m3.

Trace element data revealed low concentrations of all elements analyzed except sulfates, which were about 5 $ug/m^3$. Measured gaseous pollutant concentrations revealed carbon monoxide concentrations below the federal primary

one-hour standard but above the federal eight-hour standard. The concentration of carbon monoxide was above both the Montana one- and eight-hour standards. The remaining pollutants were below all federal and Montana standards.

# V. COLUMBIA FALLS/HARDIN/EAST HELENA/COLSTRIP

This chapter summarizes the ambient air quality data collected in the Columbia Falls, Hardin, East Helena, and Colstrip (coal development) areas. Since these areas received less intensive monitoring under MAPS than the more populated areas of Anaconda, Billings, Butte, and Missoula, the air quality levels in these four areas are discussed collectively. Data on total suspended particulates, sulfur dioxide, and fine particulates are discussed.

Columbia Falls is located at the northeastern end of the Flathead Valley in northwestern Montana. The elevation of the area varies from less than 2000 feet to more than 10,000 feet in the surrounding mountains. The terrain varies from low elevation, fertile valleys to alpine wilderness, and the climate varies with the elevation and the terrain. The centers of population, mostly in the larger valleys, tend to have milder climates than most areas of the state. Sources of air pollution at Columbia Falls include the Anaconda Aluminum Plant and several wood-products enterprises. Dust produced by automobile travel and agricultural operations also are significant air pollution sources.

The Hardin area, located in southcentral Montana, is on the western edge of the coal development area. The area is generally rolling terrain and river breaks caused by the Big Horn River. Hardin is located east and north of most of the higher mountain ranges. Therefore, the temperature inversions characteristic of western Montana valleys are not as evident in Hardin, although air stagnation episodes do occur when high pressure cells form over the area during the winter.

East Helena, located approximately three miles east of Helena in the west-central portion of Montana, is a rapidly growing area with significant subdivision development. The area is about 4000 feet above sea level in the Helena Valley. The surrounding mountains influence the climate as in other western valleys, although the Helena Valley is located east of the Continental Divide. Major industrial activity includes a lead-zinc smelter, a cement plant, and a batch plant. The smelter is a source of sulfur dioxide, particulates, and carbon monoxide, while the other activities are primarily sources of particulates. The urban growth in the area, agricultural operations, and unpaved roads also are significant sources of particulates.

Colstrip, located in southeastern Montana, is in the center of a major coal development region, which is essentially rolling plains with some smaller mountains and buttes. The climate is harsh with long, cold winters and hot, dry summers. Industries include agriculture, timber production, and coal development, which coupled with unpaved roads, produce particulate emissions.

## A. METHODOLOGY

Prior to MAPS, the Air Quality Bureau operated various ambient air monitoring stations in the four areas depending on the amount and type of air pollution emissions in the area. With the advent of MAPS, the number of stations and air pollutants monitored was increased. Primary emphasis of the air quality monitoring program was placed on areas experiencing the greatest population exposure. Table 49 lists the various sampling sites operated during MAPS in the four study areas, the parameters sampled, the analysis method used in obtaining the data, and the area type. Primarily, most sites were operated to measure total suspended particulates. Many of the same sites also measured fine particulate concentrations and sulfur dioxide.

TABLE 49
COLUMBIA FALLS/HARDIN/EAST HELENA/COLSTRIP
SAMPLING SITES AND PARAMETERS

| Site | Location (Area Type) | Parameters Sampled | Analysis Method |
|---|---|---|---|
| Anders Res. | Columbia Falls (Residential) | Total Suspended Particulates<br>Fine Particulates<br>Trace Elements | Gravimetric-High Volume Air Sampler<br>Gravimetric-Dichotomous Air Sampler<br>Atomic Absorption-High Volume Air Samples |
| N of Anaconda Aluminum | N. of Columbia Falls (Rural) | Total Suspended Particulates<br>Trace Elements | Gravimetric-High Volume Air Sampler<br>Atomic Absorption - High Volume Air Samples |
| Strom | Central Kalispell (Residential) | Total Suspended Particulates<br>Fine Particulates<br>Trace Elements<br>(Sulfates & Nitrates) | Gravimetric-High Volume Air Sampler<br>Gravimetric - Dichotomous Air Sampler<br>Colorimetric and Reduction Diazo Coupling |
| Universal Athletic | Central Kalispell (Commercial) | Total Suspended Particulates<br>Fine Particulates<br>Trace Elements<br>(Sulfates & Nitrates) | Gravimetric-High Volume Air Sampler<br>Gravimetric - Dichotomous Air Sampler<br>Colorimetric and Reduction Diazo Coupling |
| Polson | E of Polson (Rural-Industrial) | Total Suspended Particulates<br>Fine Particulates<br>Trace Elements<br>(Sulfates & Nitrates)<br>Trace Elements | Gravimetric-High Volume Air Sampler<br>Gravimetric - Dichotomous Air Sampler<br>Colorimetric and Reduction Diazo Coupling<br><br>High Volume Air Samplers<br>Dichotomous Air Samples |
| Ronan | S of Ronan (Rural) | Total Suspended Particulates<br>Trace Elements<br>(Sulfates & Nitrates | Gravimetric-High Volume Air Sampler |
| Warren Ranch | Hardin (Rural) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| Thomas Ranch | Decker (Rural) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| Randall Ranch | W. of Broadus (Rural) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |

| Site | Location(Area Type) | Paramenters Sampled | Analysis Method |
|---|---|---|---|
| BN | SE of Colstrip (Rural-Industrial) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements (Sulfates & Nitrates) | Gravimetric-High Volume Air Sampler |
| McRae | SE of Colstrip (Rural) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| E. Helena A&W | E. East Helena (Commercial) | Sulfur Dioxide | Pulsed Fluorescent |
| | | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements | Atomic Absorption - High Volume Sair Samples |
| East Stack | SE of East Helena (Rural) | Sulfur Dioxide | Coulometric |
| | | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements | Atomic Absorption - High Volume Sair Samples |
| Broudy Ranch | S. of East Helena (Rural) | Sulfur Dioxide | Coulometric |
| Hastie Res. | S. of East Helena (Residential-Industrial) | Total Suspended Particulates | Gravimetric-High Volume Air Sampler |
| | | Trace Elements | Atomic Absorption - High Volume Sair Samples |

In the northwestern portion of the state, monitoring was conducted during MAPS at two sites in or near Columbia Falls, two sites in Kalispell, and at one site each in Polson and Ronan. The majority of the northwestern Montana sampling sites was operated under the Flathead River Basin Environmental Impact Study (Gelhaus et al., 1979). In the Colstrip-Hardin coal development area of eastern Montana, five sites were operated at one time or another during MAPS, including two southeast of Colstrip, one near Hardin, one near Decker, and one near Broadus. Primary emphasis was placed on measuring total suspended particulates. In the East Helena area, monitoring was conducted during MAPS at four sampling sites around the smelter, primarily for sulfur dioxide and particulates.

Data are presented in this chapter by air pollutant, starting with the most common, (total suspended particulates), through the related parameters, and gaseous pollutants. Comparisons are made with the Montana Ambient Air Quality Standards (MAAQS) and the National Ambient Air Quality Standards (NAAQS), which are listed in Tables 2 and 3, respectively. The national or federal standards include both the primary and secondary standards.

## B. PRESENTATION OF RESULTS

### 1. Total Suspended Particulates

Total suspended particulate concentrations as measured by high-volume air samplers are summarized in Tables 50 and 51. Table 50 lists the highest-, second-highest, and third-highest concentrations of particulates at each site measured during the time periods shown. The second-highest and third-highest concentrations are shown in addition to the highest, as the Montana and federal ambient standards allow one excursion of the twenty-four hour standard during a year without a violation occurring. The second excursion at the same site

TABLE 50
Columbia Falls/Hardin/East Helena/Colstrip Area Particulate Summary
(Values in Micrograms Per Cubic Meter)

| | MAXIMUM READINGS | | | ARITHMETIC | | GEOMETRIC | | NO. OF | TIME |
|---|---|---|---|---|---|---|---|---|---|
| SITE | High | 2nd High | 3rd High | Mean | Std. Dev. | Mean | Std. Dev. | Observ. | Period |
| Polson, Lake Co. | 202 | 191 | 188 | 72 | 55 | 55 | 2.2 | 64 | Feb.79-June80 |
| Anders Columbia Falls | 484 | 426 | 423 | 130 | 95 | 96 | 2.2 | 147 | Jan.78-June80 |
| N. of Anaconda Alum. Columbia Falls | 64 | 60 | 59 | 26 | 15 | 22 | 2.0 | 146 | Jan.78-June80 |
| Strom, Kalispell | 343 | 289 | 208 | 88 | 54 | 79 | 2.2 | 64 | Oct.78-May80 |
| Universal Athletic Kalispell | 197 | 192 | 141 | 97 | 47 | 87 | 1.6 | 18 | Jan.80-June80 |
| Ronan, Lake County | 406 | 311 | 288 | 97 | 76 | 69 | 2.3 | 80 | Nov.78-June80 |
| Warren Ranch, Hardin | 135 | 113 | 100 | 27 | 25 | 18 | 2.5 | 86 | Jan.78-Feb.80 |
| Thomas Ranch, Decker | 209 | 139 | 134 | 49 | 32 | 41 | 1.8 | 97 | Jan.78-June78<br>Jan.79-June80 |
| A & W, E. Helena | 329 | 158 | 138 | 80 | 59 | 67 | 1.7 | 27 | Dec.79-June80 |
| Hastie Res. East Helena | 349 | 346 | 324 | 95 | 52 | 82 | 1.7 | 142 | Jan.78-June80 |
| BN Colstrip | 174 | 165 | 138 | 46 | 44 | 29 | 3.0 | 45 | June78-Sep.79 |
| McRae, Colstrip | 69 | 54 | 32 | 19 | 16 | 14 | 2.2 | 23 | Jan.79-Sep.79 |
| Randall Ranch Broadus | 56 | 51 | 48 | 23 | 14 | 18 | 2.2 | 30 | Jan.78-Sep.78 |

TABLE 51
Columbia Falls/Hardin/East Helena/Colstrip Area Monthly Average Particulate Levels
(Values in Micrograms Per Cubic Meter)

| Month | Polson Max | Polson Ave | Anders Max | Anders Ave | North Anac. Alum. Max | North Anac. Alum. Ave | Strom Max | Strom Ave | Univ. Athletic Max | Univ. Athletic Ave | Ronan Max | Ronan Ave | Warren Max | Warren Ave | Thomas Max | Thomas Ave | A & W Max | A & W Ave | Hastie Max | Hastie Ave | DN Max | DN Ave | McRae Max | McRae Ave | Randall Max | Randall Ave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan78 | | | 78 | 47 | 55 | 23 | | | | | | | 28 | 15 | 209 | 84 | | | 130 | 130 | | | | | 18 | 9 |
| Feb | | | 209 | 80 | 47 | 25 | | | | | | | 19 | 15 | 55 | 45 | | | 103 | 54 | | | | | | |
| Mar | | | 426 | 292 | 42 | 33 | | | | | | | 27 | 13 | 75 | 60 | | | 163 | 104 | | | | | | |
| Apr | | | 328 | 137 | 21 | 13 | | | | | | | 68 | 45 | 88 | 88 | | | 76 | 66 | | | | | 51 | 28 |
| May | | | 208 | 157 | 46 | 26 | | | | | | | 20 | 15 | 33 | 33 | | | 160 | 109 | | | | | 27 | 15 |
| Jun | | | 208 | 117 | 33 | 21 | | | | | | | 30 | 19 | 81 | 81 | | | 170 | 143 | 42 | 32 | | | 34 | 18 |
| Jul | | | 311 | 154 | 48 | 28 | | | | | | | 72 | 56 | | | | | 130 | 77 | 91 | 40 | | | 33 | 25 |
| Aug | | | 375 | 177 | 37 | 29 | | | | | | | 100 | 60 | | | | | 129 | 98 | | | | | 48 | 32 |
| Sep | | | 186 | 137 | 30 | 26 | | | | | | | 44 | 30 | | | | | | | | | | | 56 | 36 |
| Oct | | | 249 | 165 | 59 | 39 | 110 | 85 | | | | | 46 | 37 | | | | | 201 | 143 | 138 | 138 | | | | |
| Nov | | | 152 | 102 | 53 | 24 | 99 | 67 | | | 170 | 85 | 20 | 11 | | | | | 111 | 61 | 112 | 40 | | | | |
| Dec | | | 58 | 35 | 16 | 8 | 63 | 43 | | | 32 | 19 | 15 | 9 | 49 | 49 | | | 76 | 51 | 8 | 5 | | | | |
| Jan79 | | | 113 | 890 | 48 | 32 | 59 | 41 | | | 58 | 36 | 12 | 8 | 79 | 43 | | | 90 | 64 | | | 9 | 6 | | |
| Feb | 25 | 25 | 79 | 51 | 50 | 27 | 59 | 58 | | | 64 | 49 | 42 | 19 | 49 | 27 | | | 124 | 87 | | | 14 | 8 | | |
| Mar | 75 | 48 | 353 | 169 | 37 | 21 | 343 | 164 | | | 123 | 76 | 13 | 10 | 41 | 32 | | | 92 | 83 | 40 | 22 | 21 | 14 | | |
| Apr | 94 | 48 | 257 | 174 | 63 | 22 | 184 | 147 | | | 168 | 94 | | | 49 | 40 | | | 86 | 62 | 27 | 19 | 31 | 19 | | |
| May | 149 | 96 | 375 | 205 | 44 | 28 | 135 | 107 | | | 147 | 130 | 52 | 44 | 46 | 31 | | | 170 | 99 | 82 | 35 | 16 | 16 | | |
| Jun | 169 | 106 | 261 | 186 | 35 | 29 | 76 | 63 | | | 311 | 227 | 40 | 27 | 112 | 52 | | | 107 | 81 | 67 | 38 | 69 | 39 | | |
| Jul | 63 | 59 | 254 | 161 | 42 | 30 | 140 | 95 | | | 224 | 204 | 74 | 50 | 69 | 56 | | | 181 | 103 | 98 | 71 | | | | |
| Aug | 188 | 98 | 210 | 119 | 57 | 32 | 156 | 73 | | | 240 | 140 | 113 | 113 | 129 | 65 | | | 128 | 70 | 174 | 103 | 54 | 40 | | |
| Sep | 191 | 133 | 279 | 240 | 43 | 33 | 208 | 126 | | | 288 | 176 | 75 | 49 | 134 | 81 | | | 150 | 94 | 42 | 35 | 32 | 24 | | |
| Oct | 202 | 106 | 484 | 207 | 49 | 33 | | | | | 406 | 137 | 32 | 28 | 28 | 23 | | | 149 | 103 | | | | | | |
| Nov | 71 | 48 | 212 | 112 | 60 | 34 | 136 | 87 | | | 29 | 27 | 21 | 13 | 133 | 48 | | | 171 | 103 | | | | | | |
| Dec | 43 | 30 | 84 | 48 | 64 | 31 | 110 | 67 | | | 69 | 53 | 135 | 41 | 70 | 37 | 158 | 104 | 182 | 119 | | | | | | |
| Jan80 | 177 | 98 | 188 | 83 | 35 | 24 | 137 | 137 | 123 | 80 | 140 | 61 | 16 | 12 | 46 | 36 | 108 | 78 | 119 | 95 | | | | | | |
| Feb | 62 | 40 | 81 | 48 | 43 | 20 | | | 126 | 72 | 168 | 89 | 9 | 6 | 38 | 31 | 116 | 77 | 131 | 103 | | | | | | |
| Mar | 37 | 27 | 140 | 108 | 21 | 17 | | | 197 | 169 | 106 | 88 | | | 35 | 29 | 63 | 62 | 76 | 73 | | | | | | |
| Apr | 114 | 74 | 225 | 139 | 28 | 18 | 126 | 122 | 192 | 113 | 220 | 146 | | | 139 | 69 | 67 | 64 | 108 | 83 | | | | | | |
| May | 42 | 31 | 122 | 73 | 45 | 24 | 150 | 113 | 138 | 138 | 80 | 56 | | | 70 | 46 | 329 | 138 | 349 | 252 | | | | | | |
| June | 51 | 47 | 125 | 82 | 53 | 31 | | | 95 | 81 | 88 | 61 | | | 98 | 50 | 67 | 48 | 117 | 82 | | | | | | |

constitutes a violation of the standards. Among the thirteen sites shown in Table 50, concentrations exceeding the twenty-four hour federal primary value of 260 micrograms per cubic meter (ug/m$^3$) occurred at five sites: Anders in Columbia Falls, Strom in Kalispell, Ronan in Lake County, A & W in East Helena, and Hastie in East Helena. The second-highest concentration at these same sites also exceeded the federal primary value, except at the A & W site. However, a second excursion does not automatically constitute a violation of the standard as both excursions must occur within the same year. In the case of these sites, the second or third excursion did occur within the same twelve months at the sites of Hastie in East Helena, Strom in Kalispell, Ronan in Lake County, and Anders in Columbia Falls. Similarly, the federal secondary twenty-four hour value of 150 ug/m$^3$ was exceeded by the highest and second-highest excursions at eight of the sites. The highest twenty-four hour particulate concentration measured was 484 ug/m$^3$, which occurred at Anders in Columbia Falls. The Montana twenty-four hour particulate standard of 200 ug/m$^3$ was exceeded at seven sites. Second excursions of the Montana standard occurred at Anders in Columbia Falls, Strom in Kalispell, Ronan in Lake County, and Hastie in East Helena.

Table 50 also lists the arithmetic mean, arithmetic standard deviation, geometric mean, geometric standard deviation, and number of observations taken. Both the arithmetic and geometric means are listed in Table 50, as the Montana annual standard is based on an arithmetic mean of any twelve consecutive months, whereas the federal primary and secondary annual standards are based on a geometric mean of the particulate concentrations measured in any twelve consecutive months. The federal primary annual standard of 75 ug/m$^3$ was exceeded

at Anders in Columbia Falls, Strom in Kalispell, Universal Athletic in Kalispell and Hastie in East Helena during the periods sampled under MAPS. The geometric means presented in Table 50 are in some cases the means over more than a year's period. Therefore, these excursions do not necessarily constitute violations. Likewise, the federal secondary annual value of 60 ug/m$^3$ was exceeded at the same site, in addition to Ronan in Lake County and A & W in East Helena. The Montana annual standard of 75 ug/m$^3$ (arithmetic) was exceeded at Anders in Columbia Falls, Strom in Kalispell, Universal Athletic in Kalispell, Ronan in Lake County, A & W in East Helena, and Hastie in East Helena. The maximum geometric mean and arithmetic mean occurred at Anders in Columbia Falls (96 and 130 ug/m$^3$, respectively). All samplers were run on the standard schedule of one sample every six days.

Table 51 lists the monthly arithmetic average total suspended particulate concentrations measured at the thirteen sites. Also listed are the maximum twenty-four hour concentrations of particulates for each month. In Table 50 the trend for the Polson area appears to indicate highest particulate concentrations during the early autumn and lowest concentrations during the spring. The monthly averages varied from 25 ug/m$^3$ in February 1979 to 133 ug/m$^3$ in September 1979. In Columbia Falls (the Anders site), the trend was similar to that at Polson. However, in addition to high particulate concentrations in the autumn, high concentrations occurred during the spring. Lowest concentrations occurred at the Anders site during the winter. The particulate averages varied from 35 ug/m$^3$ in December 1978 to 292 ug/m$^3$ in March 1978. At the North of Anaconda Aluminum (NAAC) site to the north of Columbia Falls, concentrations of particulates were much lower than at the Anders site in Columbia Falls. At the NAAC site, the seasonal trend was not as apparent as at other sites. Month to month variations generally were small. Average concentrations

varied from 8 ug/m$^3$ in December 1978 to 39 ug/m$^3$ in October 1978. In Kalispell the particulate concentrations appeared to follow that of the Anders site with highest concentrations in the autumn and again during the spring. Concentration averages varied from 41 ug/m$^3$ in January 1979 to 164 ug/m$^3$ in March 1979. The Ronan site in Lake County reversed all trends found at the previous sites. Highest particulate concentrations were noted during the summer and lowest concentrations during the winter.

In the Hardin-Colstrip areas of eastern Montana, concentrations of particulates were much lower than most sites in the Columbia Falls-Kalispell area. At the Warren site near Hardin, concentrations varied from 6 ug/m$^3$ in February 1980 to 113 ug/m$^3$ in August 1979. Seasonal trends indicated higher concentrations during the late summer and lower concentrations in the winter. At the Thomas site near Decker the trend was not as clear. Furthermore, month to month variations generally were small. Average concentrations varied from 23 ug/m$^3$ in October 1979 to 88 ug/m$^3$ in April 1978. The Randall, BN, and McRae sites had too little data available to reveal any seasonal trends.

In East Helena, only the Hastie site had enough useful data to describe a trend. Generally, highest concentrations occurred during the summer and autumn and lowest concentrations during the winter. Concentration averages varied from 51 ug/m$^3$ in December 1978 to 232 ug/m$^3$ in May 1980.

2. Inhalable Suspended Particulates

During the MAPS monitoring program, a network of samplers was established throughout the state to measure the concentrations of fine suspended particulates. See Chapter II for a description of this network. Two samplers were located in the Columbia Falls-Kalispell area, at Anders in Columbia Falls and Strom in Kalispell. The Strom sampler was moved eventually to the Universal Athletic site in Kalispell.

Tables 52 through 54 summarize the fine particulate data for the three sites. Shown in the tables are monthly average values of concentrations from the two size ranges, the total fine particulates, and the total suspended particulates as measured by a high-volume air sampler. In Table 52 (the data for Anders in Columbia Falls), the particles less than 2.5 microns showed the least amount of variation. Concentrations varied from 8 ug/m$^3$ in March 1980 to 32 ug/m$^3$ in April 1980. Because the sampler was operated from January through June 1980, no seasonal or overall trend is available. Particles from 2.5 to 15 microns showed much more variation in concentration from month to month. Averages varied from 6 ug/m$^3$ in February 1980 to 80 ug/m$^3$ in April 1980. Contribution of the fine fraction, or particles less than 2.5 microns, to the total fine particulate concentration at the Anders site varied from 16 percent in June 1980 to 75 percent in February 1980. Conversely, the coarse fraction or particles from 2.5 to 15 microns varied from a contribution of 25 percent to 84 percent.

At the Strom site in Kalispell, data were available for only three months. Concentrations of particles less than 2.5 microns averaged 17 ug/m$^3$, which is very similar to the average at Anders in Columbia Falls (18 ug/m$^3$ averge). However, the variation in monthly averages at Strom was very little, as values ranged from 15 ug/m$^3$ in September 1978 to 19 ug/m$^3$ in October 1978. Concentrations of particles from 2.5 to 15 microns varied from 12 ug/m$^3$ in November 1978 to 23 ug/m$^3$ in October 1978. Contributions to the inhalable particulate concentration varied from 43 to 55 percent for the coarse fraction and 45 to 57 percent for the fine fraction.

At the Universal Athletic site in Kalispell, data were available from January through June 1980. Average concentrations of particles less than 2.5 microns

TABLE 52
Anders Residence-Columbia Falls
Monthly Average Particulate Data
(Values in Micrograms Per Cubic Meter)

| Month | Total Susp. Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Jan 80 | 83 | 31 | 31 | 62 |
| Feb | 48 | 18 | 6 | 24 |
| Mar | 108 | 8 | 40 | 48 |
| Apr | 139 | 32 | 80 | 112 |
| May | 73 | 11 | 46 | 57 |
| June | 82 | 12 | 62 | 74 |

TABLE 53
Strom-Kalispell Monthly Average Particulate Data
(Values in Micrograms Per Cubic Meter)

| Month | Total Susp. Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Sep78 | -- | 15 | 16 | 31 |
| Oct | 85 | 19 | 23 | 42 |
| Nov | 67 | 17 | 12 | 28 |

TABLE 54
Universal Athletic Kalispell Monthly Average Particulate Data
(Values in Micrograms Per Cubic Meter)

| Month | Total Susp. Particulates | Susp. Part. 2.5 microns | Susp. Part. 2.5 to 15 microns | Susp. Part. 15 microns |
|---|---|---|---|---|
| Jan80 | 80 | 32 | 32 | 64 |
| Feb | 72 | 24 | 31 | 55 |
| Mar | 169 | 14 | 44 | 59 |
| Apr | 113 | 13 | 46 | 60 |
| May | 138 | 9 | 40 | 49 |
| June | 81 | 9 | 45 | 54 |

varied from 9 ug/m$^3$ in May and June 1980 to 32 ug/m$^3$ in January 1980. Particles from 2.5 to 15 microns varied much less in concentration. Values varied from 31 ug/m$^3$ in February 1980 to 46 ug/m$^3$ in April 1980. Contributions to the inhalable particulate concentration varied from 17 to 50 percent for the fine fraction and 50 to 83 percent for the coarse fraction.

3. Trace Elements

Chemical analyses were performed during MAPS on the high-volume air samples for a variety of trace elements by means of atomic absorption. The results of these analyses are presented in Tables 55 and 56. Shown in the tables are arithmetic average trace element concentrations, which are shown as zero if actual concentrations were analyzed below the detection limit of the analysis method.

In Table 55 aluminum concentrations varied from 0.31 ug/m$^3$ at North of Anaconda Aluminum (NAAC) site north of Columbia Falls to 1.05 ug/m$^3$ at the Hastie in East Helena. The Anders site in Columbia Falls and BN at Colstrip averaged 0.49 and 0.63 ug/m$^3$, respectively. Arsenic concentrations revealed lowest concentrations in the Columbia Falls area with the East Helena sites measuring the highest concentrations. Hastie in East Helena received 0.215 ug/m$^3$ average arsenic concentrations, whereas NAAC north of Columbia Falls received only 0.002 ug/m$^3$. BN at Colstrip also measured very low concentrations. Cadmium concentrations also showed the same trend with lowest concentrations near Columbia Falls and highest concentrations in East Helena. Similar trends were noted for copper, iron, and lead. Manganese concentrations varied little from area to area. Nickel concentrations reversed the trend of the previous trace elements, as nickel values were highest at BN in Colstrip

TABLE 55
Columbia Falls/East Helena/Colstrip Area
Average Trace Element Data*
(Values in Micrograms Per Cubic Meter)

Arithmetic Mean

| Element | Anders Columbia Falls | N. Anac. Alum. Columbia Falls | A & W E. Helena | Hastie E. Helena | BN Colstrip |
|---|---|---|---|---|---|
| Aluminum | 0.49 | 0.31 | | 1.05 | 0.63 |
| Arsenic | 0.003 | 0.002 | 0.110 | 0.215 | 0.009 |
| Cadmium | 0.002 | 0.016 | 0.072 | 0.157 | 0.029 |
| Chromium | | | 0.000 | 0.006 | |
| Copper | 0.039 | 0.03 | 1.35 | 2.87 | 0.07 |
| Iron | 0.84 | 0.22 | | 1.44 | 1.42 |
| Lead | 0.45 | 0.07 | 0.74 | 3.31 | 0.11 |
| Manganese | 0.06 | 0.04 | 0.05 | 0.09 | 0.106 |
| Nickel | 0.020 | 0.057 | 0.003 | 0.032 | |
| Vanadium | | | 0.00 | 0.01 | |
| Zinc | 0.23 | 0.03 | | 4.47 | 0.13 |
| Nitrate | 1.2 | 0.8 | 2.4 | 1.8 | 1.1 |
| Sulfate | 3.7 | 3.3 | 7.4 | 8.0 | 4.6 |

TABLE 56
Columbia Falls/East Helena/Colstrip Area
Average Sulfate and Nitrate Data*
(Values in Micrograms Per Cubic Meter)

Arithmetic Mean

| Site | Sulfate | Nitrate |
|---|---|---|
| Polson, Lake County | 3.2 | 1.3 |
| Anders, Columbia Falls | 3.7 | 1.2 |
| N.Anac. Alum., Columbia Falls | 3.3 | 0.8 |
| Univ. Athletic, Kalispell | 4.0 | 2.1 |
| Strom, Kalispell | 4.1 | 1.8 |
| Ronan, Lake County | 3.2 | 1.6 |
| A & W, East Helena | 7.4 | 2.4 |
| Hastie, East Helena | 8.0 | 1.8 |
| BN, Colstrip | 4.6 | 1.1 |

*Collection method - high-volume air sampler (glass fiber filters) and atomic absorption analysis.

and second highest at NAAC north of Columbia Falls. East Helena nickel concentrations were lowest. Zinc, on the other hand, revealed very high concentrations at Hastie in East Helena, but low concentrations at A & W in East Helena. Other areas of the state also were low.

Nitrate and sulfate concentrations for all sites in the Columbia Falls/Colstrip/Hardin/East Helena areas are summarized in Table 56. Sulfate values range from 3.2 ug/m$^3$ at Polson and Ronan (Lake County) to 7.4 and 8.0 at A & W and Hastie in East Helena, respectively. Generally, all the sites measured sulfate values from 3.2 to 4.6 ug/m$^3$ except for the East Helena sites. Nitrate values ranged from 0.8 ug/m$^3$ at NAAC north of Columbia Falls to 2.4 ug/m$^3$ at A & W in East Helena. Much less variation was presented in the nitrate concentrations than in the sulfate concentrations.

4. Gaseous Pollutants

Sampling was performed for sulfur dioxide at the East Helena stations during MAPS. Three stations were used to measure the sulfur dioxide for varying time periods, and the results of the sampling are summarized in Table 57.

The East Helena Stack sampler was operated from January 1978 to November 1979. The maximum one-hour sulfur dioxide concentration measured was 0.48 parts per million (ppm), which compares with the Montana one-hour standard of 0.50 ppm, not to be exceeded more than eighteen times in any twelve consecutive months. The corresponding maximum three-hour sulfur dioxide concentation at East Stack was 0.25 ppm. This value also falls below the federal secondary three-hour standard of 0.50 ppm, not to be exceeded more than once per year. The maximum twenty-four hour concentration of sulfur dioxide measured at the East Stack station was 0.08 ppm compared to the Montana and federal primary

TABLE 57
East Helena Area Sulfur Dioxide Data Summary
(Values in Parts Per Million)

| AVERAGING TIME | EAST STACK (Jan.78-May79,Oct.79-Nov.79) | BROUDY RANCH (Jan.78-Feb.80) | A & W (Nov.79-June80) |
|---|---|---|---|
| 1-hour max. (high) | 0.48 | 0.80 | 0.26 |
| 1-hour max. (2nd high) | 0.34 | 0.49 | 0.20 |
| 3-hour max. (high) | 0.25 | 0.41 | 0.19 |
| 3-hour max. (2nd high) | 0.21 | 0.27 | 0.14 |
| 24-hour max. (high)+ | 0.08 | 0.11 | 0.04 |
| 24-hour max. (2nd high) | 0.05 | 0.10 | 0.03 |
| Average* | 0.006 | 0.004 | 0.008 |
| No. of Readings | 8,923 | 15,294 | 3,728 |

*Time period of average varies by site
+Midnight to midnight

twenty-four hour standards of 0.10 and 0.14 ppm, respectively. The average sulfur dioxide concentration at East Stack station during the sampling period was 0.006 ppm. The Montana and federal primary annual standards are 0.02 and 0.03 ppm, respectively.

The Broudy Ranch monitor was operated from January 1978 to February 1980. The maximum one-hour sulfur dioxide concentration measured was 0.80 ppm, and the second highest one-hour concentration was 0.49 ppm. (The Montana standard allows eighteen one-hour concentrations in excess of the standard before a violation occurs.) The maximum three-hour concentration measured at the Broudy site was 0.41 ppm, which falls below the federal secondary three-hour standard. The maximum twenty-four hour concentration measured was 0.11 ppm, which exceeds the Montana twenty-four hour standard. However, the standard allows one excursion before a violation occurs. The second highest twenty-four hour concentration was 0.10 ppm. The average concentration at the Broudy site over the sampling period was 0.004 ppm.

At the A & W site in East Helena, which was operated during MAPS from November 1979 to June 1980, the maximum one-hour, three-hour, and twenty-four hour sulfur dioxide concentrations measured were 0.26, 0.19, and 0.04 ppm, respectively. All of these concentrations fall below the Montana and federal ambient standards. The average concentration measured during the sampling period was 0.008 ppm.

## C. SUMMARY AND CONCLUSIONS

MAPS provided valuable data on air pollution levels found in the Columbia Falls, Hardin, East Helena, and Colstrip areas. Data were collected on concentrations of total suspended particulates, fine particulates, trace elements, and gaseous pollutants. Total suspended particulate concentrations were in excess of federal and state standards in Columbia Falls, Kalispell, Ronan, and East Helena. Generally, highest concentrations were measured in the early autumn and lowest concentrations in the late winter or spring.

Fine particulate data collected in the Kalispell and Columbia Falls area were not available for an extensive period to reveal any seasonal trends. Generally, the fine fraction of the inhalable particulates comprised about 50 percent of the total concentration.

Trace element data generally revealed low concentrations of all elements.

Gaseous pollutants measured included only sulfur dioxide at East Helena. Concentrations were at or below all federal and Montana standards.

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# GLOSSARY

| | |
|---|---|
| Air Pollution | The general term alluding to the undesirable addition to the atmosphere of substances (gases, liquids and solid particles) either that are foreign to the "natural" atmosphere or in quantities exceeding their natural concentrations. |
| Air Quality | The composition of air with respect to quantities of pollutants therein; used most frequently in connection with "standards" of maximum acceptable pollutant concentrations. |
| Ambient Air | Literally, the air moving around us; the air of the surrounding environment. It is used, generally in opposition to closed, controlled environments of any kind. In the Montana "standards" it is defined as "that portion of the atmosphere external to buildings, to which the general public has access." |
| Ambient Air Quality Standards | A permissible level of an air contaminant in the ambient air as defined by the maximum frequency with which a specified level may be exceeded or by a maximum level of an air contaminent in or on body or plant tissues. |
| Arithmetic Mean | Simply the sum of all the values or readings divided by the number of values. |
| Carbon Dioxide | A heavy, colorless gas that enters the atmosphere as the result of efficient natural and artificial combustion processes; the fourth most abundant constituent of dry air. |
| Carbon Monoxide | A colorless, odorless, and very toxic gas found in trace quantities in the natural atmosphere, but also produced by the incomplete combustion of fossil fuels. The gas has the molecular composition of one carbon carbon atom and one oxygen atom. |
| Coarse Particles | Term generally used to describe a size of suspended particulates, usually particles between 2.5 and 15 microns in dimater (mean Stoke's diameter). |

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| Concentration | General term for the amount of a substance contained in a unit area or volume, or relative to the amount of medium within which the substance is contained. (See Parts Per Million or Micrograms Per Cubic Meter). |
| Dust | Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size. |
| Excursion | As used in air pollution applies to a concentration of an air contaminant in excess of ambient air quality standard. As opposed to a "violation", an excursion may not be a violation as some standards allow several excursions before a violation is said to have occurred. |
| Fine Particles | Term generally used to describe a size of suspended particulates, usually particles less than 2.5 microns in diameter. It is sometimes referred to as respirable particulates. |
| Geometric Mean | Simply the sum of the natural logarithms of the values or readings divided by the number of readings. The antilog is then taken of the resultant. Often used in ambient air quality standards for particulate matter as the geometric mean tends to smooth out the data eliminating the effect of a few high readings. |
| High-Volume Air Sampler | An instrument often used to measure the amount of particulate matter suspended in the air. The instrument pulls the ambient air through a filter which is weighed before and after exposure to the air. By also recording the amount of air pulled through the filter and the weight of particulates added to the filter, a value of particulate matter suspended in the air per unit volume of air is then calculated. |
| Inhalable Particles | Term generally used to describe a size of suspended particulates, usually particles less than 15 microns in diameter (mean Stoke's diameter). The sum of the coarse and fine particles equals the inhalable particles. |
| Micrograms Per Cubic Meter | In air pollution it is the weight of particles in micrograms (one-millionth of a gram is a microgram) per cubic meter of air. Concentrations of particulates are often expressed in this form. |

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| Microns | A unit of length equal to one-millionth of a meter. |
| Nitric Oxide | A colorless gas that enters the atmosphere as a pollutant mainly via the exhaust of automobile engines. Its principal effect in photochemical smog is to combine with oxygen to form nitrogen dioxide. |
| Nitrogen Dioxide | A reddish-brown gas that exists in photochemical smog as a scondary pollutant. |
| Oxides of Nitrogen | A term used to cover collectively all compounds of nitrogen and oxygen such as $NO$ (Nitric Oxide) and $NO_2$ (Nitrogen Dioxide). |
| Ozone | An unstable, blueish colored gas with a pungent odor. Ozone is an important constiuent of photochemical smog. |
| Particulates | Any liquid or solid particles suspended in or falling through the atmosphere. |
| Parts Per Million | In air pollution, a term used to describe a concentration of a particular air contaminant (volume or weight) per one million equal weights or volumes of atmosphere or other medium at the same condition of temperature and pressure. |
| Photochemical Smog | The type of smog typical of the Los Angeles basin but becoming more and more prevalent elsewhere. In general, it is any smog wherein secondary pollutants are produced by photochemical reactions. |
| Pollutant | (Or contaminant) With respect to the atmosphere, any substance within it that is foreigh to the "natural" atmosphere or that exceeds its "natural" concentrations in the atmosphere. |
| Primary Standard | As used in the federal ambient air quality standards refers to "levels of air quality which the Administrator of the Environmental Protection Agency judges are necessary, with an adequate marginal safety, to protect the public health." |
| Respirable Particulates | A term used to describe a size of suspended particulates usually less than 2.5 microns in diameter. |

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| Secondary Standard | As used in the federal ambient air quality standards refers to "levels of air quality which the Administrator of the Environmental Protection Agency judges necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant." |
| Sources | A point, line, area or volume at which mass or energy is added to a system, either instantaneous or continuously. In air pollution the source usually adds an air contaminant to the atmosphere. |
| Standard Deviation | A measure of the scatter or spread of a series of observations. |
| Sulfur Dioxide | A colorless, extremely irritating gas or liquid; it enters the atmosphere as a pollutant mainly as a result of burning sulfur containing fuel oils and coal. |
| Total Hydrocarbons | A term collectively describing a group of compounds that consist solely of the elements carbon and hydrogen; an important constituent in photochemical smog. |
| Total Suspended Particulates | A term used to describe all liquid and solid particulates suspended in the atmosphere, usually particles less than 100 microns in diameter. |
| Trace Elements | Chemical elements or compounds found in the atmosphere in very small quantities relative to the more abundant elements. |

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